ELEMENTS OF PHYSIOLOGY.

By the same Author,

PRINCIPLES

OF

GENERAL AND COMPARATIVE PHYSIOLOGY.

WITH NUMEROUS ILLUSTRATIONS. (AT PRESS.)

PRINCIPLES OF HUMAN PHYSIOLOGY.

WITH NUMEROUS ILLUSTRATIONS.

A POPULAR TREATISE ON VEGETABLE PHYSIOLOGY.

WITH NUMEROUS CUTS.

PUBLISHED BY LEA AND BLANCHARD.

ELEMENTS

OF

PHYSIOLOGY,

INCLUDING

PHYSIOLOGICAL ANATOMY,

FOR THE USE OF THE MEDICAL STUDENT.

BY

WILLIAM B. CARPENTER, M.D., F.R.S.,

FULLERIAN PROFESSOR OF PHYSIOLOGY IN THE ROYAL INSTITUTION OF GREAT BRITAIN;
MEMBER OF THE AMERICAN PHILOSOPHICAL SOCIETY, AND
CORRESPONDING MEMBER OF THE NATIONAL INSTITUTE OF THE UNITED STATES;
ETC. ETC.

WITH ONE HUNDRED AND EIGHTY ILLUSTRATIONS.

PHILADELPHIA:
LEA AND BLANCHARD.
1846.

PHILADELPHIA:
T. K. AND P. G. COLLINS,
PRINTERS.

AMERICAN PUBLISHERS' ADVERTISEMENT.

The sheets of this volume, in their passage through the press, have been carefully examined by Dr. Meredith Clymer, the Editor of Dr. Carpenter's "Principles of Human Physiology." The perfect adaptation of the work to its purposes as an elementary text-book, and the manner in which it is brought up to the day, have rendered unnecessary any notes or additions; the efforts of the publishers, therefore, have been directed to a correct reprint of the London edition.

That it may correspond in size with the Author's other works on Physiology, the publishers have employed a type larger than that used in the London edition, and consequently they have been induced to substitute the word "*Elements*" in place of "*Manual*," which was adopted by the Author more with reference to its original size than to its contents, as stated in his Preface.

PHILADELPHIA,
April, 1846.

PREFACE.

The present volume owes its origin to a desire, on the part of the Publisher, that an elementary treatise on Physiology should be added to the series of admirable Students' Manuals, on the various departments of Medical Science, which he has already issued. But for this desire, the Author would have preferred not again to present himself so soon before the public, in a capacity in which he fears that he has already trespassed too much on their indulgence; his wish being rather to devote as much time as possible to original inquiry in various departments of Physiology, which stand in great need of elucidation.

Although this Manual combines, in some degree, the scope of the Author's two larger works on the same subject, yet it cannot be regarded as a mere abridgment of them; having been written with very little reference to them, and on a plan which is in many respects different. His object has been to convey to the Student as clear an idea as possible of the principles of the science, to point out the manner in which these principles should be applied, and to give an outline of the most important facts which indicate the nature of the various changes taking place in the living organism. In following out this intention he has thought it right to adopt a plan which, so far as he knows, is a novel one:—namely, to commence his exposition of the characters of Organized Structures and of Vital Phenomena by a full account of the Development and Metamorphoses of *Cells*, and of the purposes which these effect in the living body, either in their original or in their altered condition. He is of opinion that the inferences, which may be drawn from the observations on this subject, that have rapidly accumulated during the last few years, are entitled to hold the same rank in Physiological Science as that taken by the doctrine of Mutual Attraction in General Physics, or of Elective Affinity in Chemistry; and that the enunciation and development of these should

consequently hold the first place in an Elementary Treatise on Physiology. The third chapter, constituting more than one-fourth of the entire Treatise, is therefore devoted to this subject. The topics embraced in the first two chapters, and in the whole of the Second Book, are treated of on a much more extended scale in the Author's "Principles of General and Comparative Physiology," and "Principles of Human Physiology," to which he would refer those who desire further information upon them. As the matter of which those volumes are composed is itself condensed to the utmost possible degree, it is manifestly impossible that the present Manual should contain more than a mere outline of the subjects of which they treat. The Author has endeavoured to select what is of the most importance to the Student, and lies most readily within his comprehension; and has rather desired to impress the minds of his readers with a clear notion of what he considers the leading or typical facts of the science, than to load his memory with details.

The Author may be permitted to direct attention to the copiousness and beauty of the illustrations, which the liberality of the Publisher has allowed him to introduce. The greater part of the wood-engravings have been executed, expressly for this volume, by Mr. Vasey, whose skill and fidelity have recently shown themselves to be as great in the treatment of anatomical subjects as they have been long known to be in the representation of objects of natural history.

Stoke Newington,
Feb. 20th, 1846.

TABLE OF CONTENTS.

BOOK I.

GENERAL PHYSIOLOGY.

BOOK II.

SPECIAL PHYSIOLOGY.

LIST OF WOOD ENGRAVINGS.

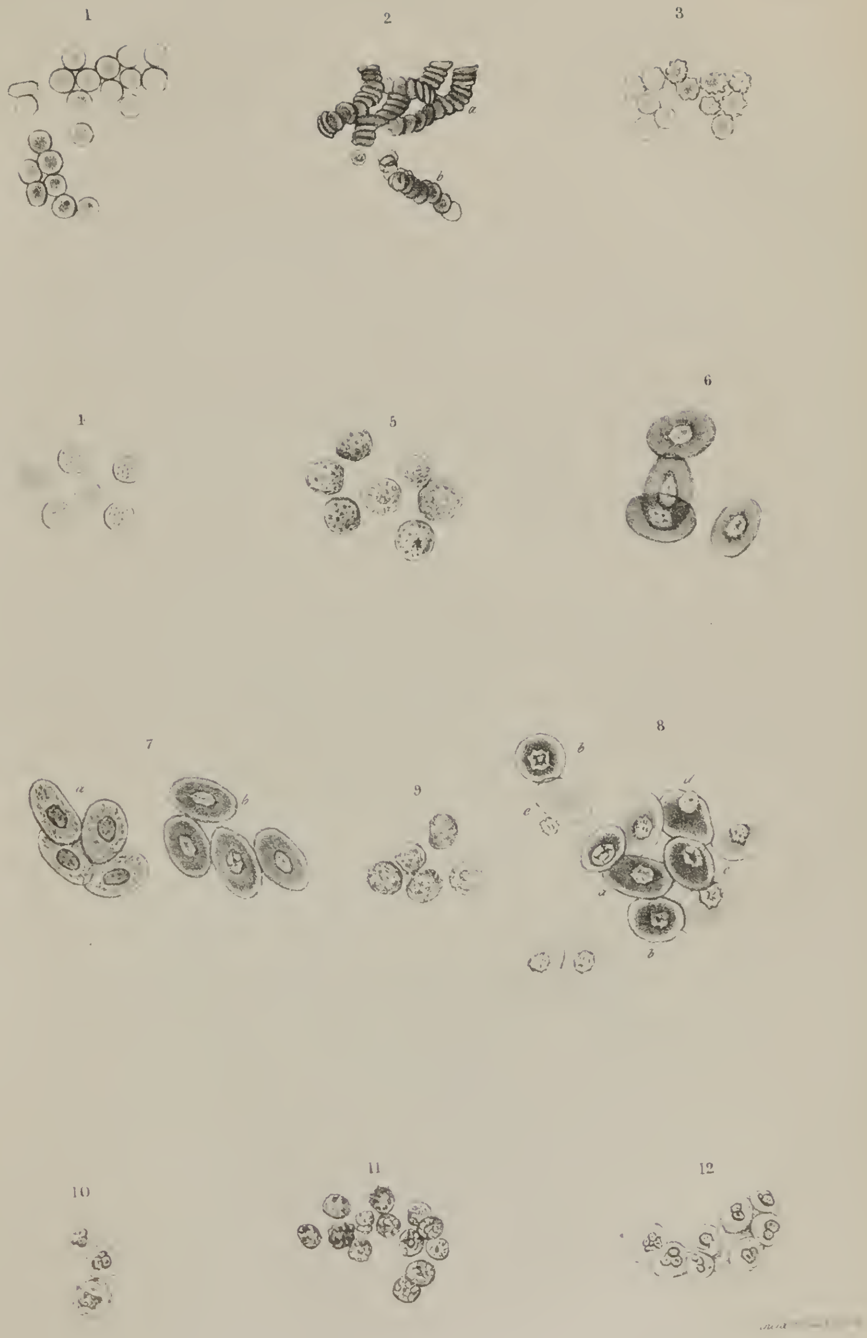
Two plates embracing 27 figures, making altogether 180 figures.

EXPLANATION OF PLATE I.

The Figures in this Plate represent the Cells floating in the various animal fluids; and they are all, with the exception of Figs. 4 and 5, copied from the representations given by M. Donné in his Atlas de l'Anatomie Microscopique. These representations are transcripts of Daguerreotype pictures, obtained from the objects, by a solar microscope, with a magnifying power of 400 diameters.

Fig. 1. Red Corpuscles of Human Blood, viewed by their flattened surfaces (§ 215).
Fig. 2. Red Corpuscles of Human Blood, adherent by their flattened surfaces, so as to form rolls;—at *a*, the entire surfaces are adherent; at *b*, their surfaces adhere only in part.
Fig. 3. Red Corpuscles of Human Blood, exhibiting the granulated appearance which they frequently present, a short time after being withdrawn from the vessels.
Fig. 4. Colourless Corpuscles of Human Blood (§ 212).
Fig. 5. The same, enlarged by the imbibition of water.
Fig. 6. Red Corpuscles of Frog's Blood (§ 215).
Fig. 7. The same, treated with dilute acetic acid; the first effect of which is to render the nucleus more distinct, as at *b*; after which the outer vesicle becomes more transparent, and its solution commences, as at *a*.
Fig. 8. The same, treated with water; at *a* is seen a corpuscle nearly unaltered, except in having the nucleus more sharply defined; at *b*, others which have become more spherical, under the more prolonged action of water; at *c*, the nucleus is quitting the centre, and approaching the circumference of the disk; at *d* it is almost freeing itself from the envelop; and at *e* it has completely escaped.
Fig. 9. Globules of Mucus, newly secreted (§ 237).
Fig. 10. The same, acted on by acetic acid.
Fig. 11. Globules of Pus, from a phlegmonous abscess (§ 632).
Fig. 12. The same, acted on by acetic acid.

PLATE I



EXPLANATION OF PLATE II.

The Figures in this Plate represent the principal forms of the Nervous Centres in different classes of animals. The 1st is copied from a recent Memoir by M. Blanchard; the 2d, 3d, and 4th, from Mr. Newport's delineations; the 5th to the 13th from the interesting work of M. Guillot on the Comparative Anatomy of the Encephalon in the different classes of Vertebrata; and the two last from the work of M. Leuret on the same subject.

Fig. 1. Nervous System of *Solen; a, a,* cephalic ganglia, connected together by a transverse band passing over the Œsophagus, and connected with the other ganglia by cords of communication; *b*, pedal ganglion, the branches of which are distributed to the powerful muscular foot; *c*, branchial ganglion, the branches of which proceed to the gills *d, d,* the siphons *e, e,* and other parts. On some of these branches, minute ganglia are seen; as also at *f, f,* on the trunks that pass forwards from the cephalic ganglia (§ 852).

Fig. 2. Nervous System of the *Larva* of *Sphinx ligustri; a,* cephalic ganglia; 1—12, ganglia of the ventral cord (§ 856).

Fig. 3. Thoracic portion of the Nervous System of the *Pupa* of *Sphinx ligustri; a, b, c,* three ganglia of the ventral cord; *d, d,* their connecting trunks; *e, e,* respiratory ganglia (§ 862).

Fig. 4. Anterior portion of the Nervous System of the *Imago* of *Sphinx ligustri; a,* cephalic ganglia; *b, b,* eyes; *c,* anterior median ganglion, and *d, d,* posterior lateral ganglia of stomato-gastric system; *e, f,* large ganglionic masses in the thorax, giving origin to the nerves of the legs and wings (§ 863).

Fig. 5. Brain of the *Perch*, seen from above (§ 869.)

Fig. 6. The same, as seen from below.

Fig. 7. Interior of the same, as displayed by a vertical section.

The following references are common to the three preceding, and to the succeeding figures.

a, a, Olfactory lobes or ganglia.
b, b, Cerebral ganglia or Hemispheres.
c, c, Optic lobes.
d, Cerebellum.
e, Spinal Cord.
f, Pineal gland.
g, Lobi inferiores (their precise character not determined).
h, Pituitary body.
i, Optic Nerves.

Fig. 8. Brain of the *Common Lizard*, seen from above (§ 871).

Fig. 9. The same, as seen from below.

Fig. 10. The same, as displayed by a vertical section.

Fig. 11. Brain of the *Common Goose*, seen from above (§ 872).

Fig. 12. The same, as seen from below.

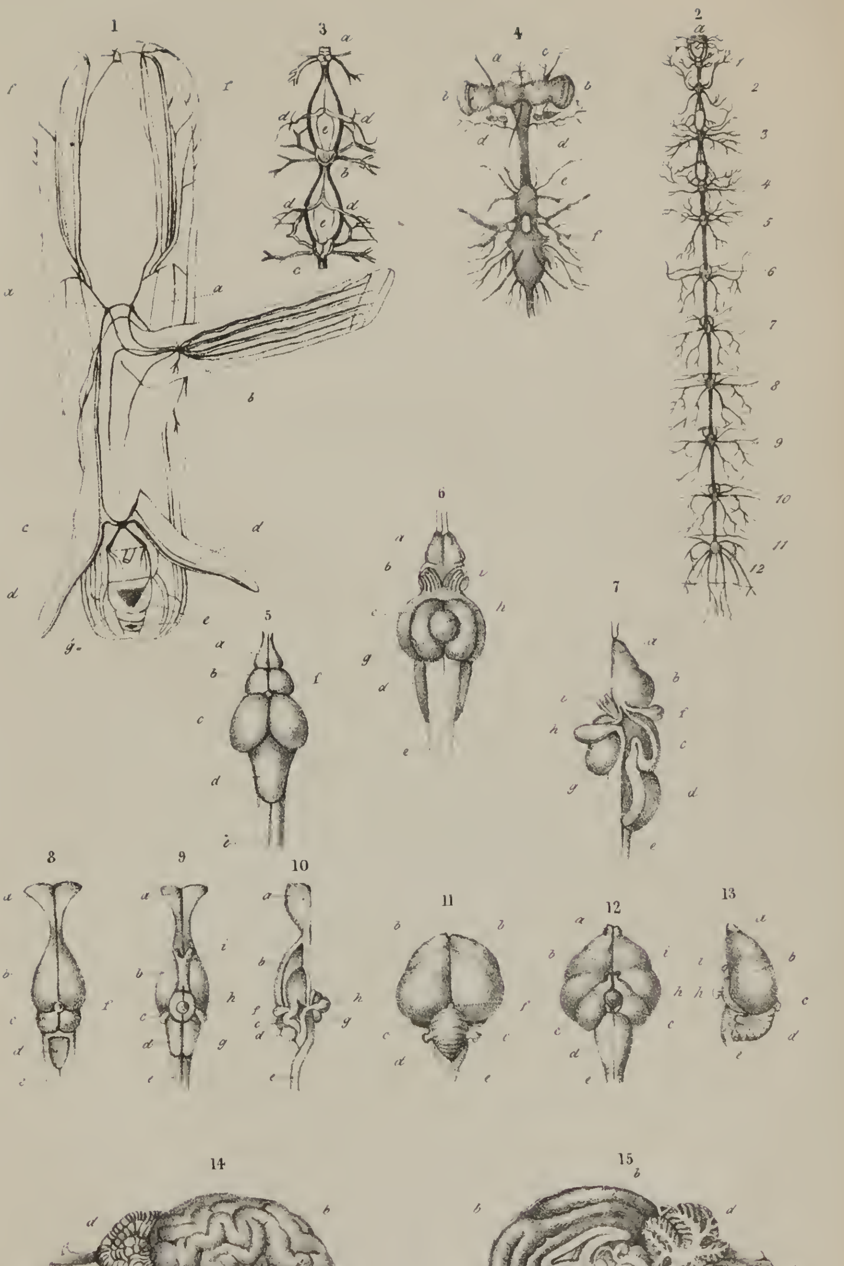
Fig. 13. The same, as displayed by a vertical section.

Fig. 14. Brain of the *Sheep*, viewed sideways (§ 873).

Fig. 15. The same, as displayed by a vertical section.

In addition to the parts indicated by the preceding references, we have here to notice;—*k*, the corpus callosum; *l*, the septum lucidum, and *m*, the Pons Varolii.

PLATE II



Sinclair's Lith Phila

BOOK I.

GENERAL PHYSIOLOGY.

CHAPTER I.

ON THE NATURE AND OBJECTS OF THE SCIENCE OF PHYSIOLOGY.

1. The general distribution of the objects presented to us by external Nature, into three kingdoms,—the animal, the vegetable, and the mineral,—is familiar to every one; and not less familiar is the general distinction between living bodies, and dead inert matter. True it is, that we cannot always clearly assign the limits, which separate these distinct classes of objects. Even the professed naturalist is constantly subject to perplexity, as to the exact boundary between the animal and the vegetable kingdoms; and the distinction between animal and vegetable structures, on the one hand, and mineral masses on the other,—or between living bodies, and aggregations of inert matter,—is by no means so obvious in every case, as to be at once perceptible to the unscientific observer. Thus, a mass of Coral, if its growing portion be kept out of view, or a solid Nullipore attached to the surface of a rock, might be easily confounded with the mineral bodies to which they bear so close a resemblance; and a minute examination might be required to detect the difference. Nevertheless, a well-marked distinction does exist between the *organized* structures of plants and animals, and the *inorganic* aggregations of Mineral matter; as well as between the condition of a *living* being, whether Animal or Plant, and that of *dead* or *inert* Mineral bodies. It is upon these distinctions, which are usually obvious enough, that the sciences of Anatomy and Physiology are founded; these sciences taking cognizance,—the former of those structures which are termed *organized*,—and the latter of the actions which are peculiar to those structures, and which are distinguished by the term *vital*. It will be desirable to consider, in a somewhat systematic order, the principal ideas which we attach to these terms; as we shall be thus led most directly to the distinct comprehension of the nature and object of Physiological science.

2

1. *Of Organic Structures.*

2. Organized structures are characterized, in the first place, by the peculiarities of their *form*. Wherever a definite form is exhibited by Mineral substances, it is bounded by straight lines and angles, and is the effect of the process termed *crystalization*. This process results from the tendency which evidently exists in particles of matter, especially when passing gradually from the fluid to the solid state, to arrange themselves in a regular and conformable manner in regard to one another. There is, perhaps, no inorganic element or combination, which is not capable of assuming such a form, if placed in circumstances adapted to the manifestation of this tendency among its particles; but if these circumstances should be wanting, and the simple cohesive attraction is exercised in bringing them together, without any general control over their direction, an indefinite or shapeless figure is the result. Neither of these conditions finds a parallel in the Organized creation. From the highest to the lowest we find the shape presenting a determinate character for each *species* or *race*, with a certain limited amount of variation amongst *individuals;* and this shape is such, that, instead of being circumscribed within plane surfaces, straight lines, and angles, organized bodies are bounded by convex surfaces, and present rounded outlines. We may usually gather, moreover, from their external form, that they are composed of a number of dissimilar parts, or *organs;* which are combined together in the one individual body, and are characteristic of it. Thus, in the Vertebrated or Articulated animal we at once distinguish the head and extremities from the trunk, which constitutes the principal mass; and where there exist no external organs of such distinctness, as in some Mollusks, the rounded character of the general form is sufficiently characteristic. The very simplest grades of animal and vegetable life present themselves under a form, which approaches more or less closely to the globular. It is among the lower tribes of both kingdoms, that we find the greatest tendency to irregular departures from the typical form of the species; and thus is presented an approach, on the one hand, to that indefiniteness which is characteristic of uncrystaline mineral masses; and, on the other, to that variety of crystaline forms which the same mineral body may present, according to the circumstances which influence its crystalization.

3. With regard to *size*, again, nearly the same remarks apply. The magnitude of Inorganic masses is entirely indeterminate, being altogether dependent upon the number of particles which can be brought together to constitute them. On the other hand, the size of Organized structures is restrained, like their form, within tolerably definite limits, which may nevertheless vary to a certain extent among the individuals of the same species. These limits are least obvious in vegetables, and in the lower classes of animals. A forest tree may

go on extending itself to an almost indefinite extent; certain species of sea-weed attain a length of many hundred feet, and their growth does not appear to undergo any check; and the same may be said of those enormous masses of coral, which compose so many islands and reefs in the Polynesian Archipelago, or of which the debris seem to have constituted many of the calcareous rocks of ancient formation. But in these cases the increase is produced, not so much by the continued development of the individual, as by the continued production of new individuals, which remain in connection with the original. Thus each bud of a tree may be regarded as a distinct individual; because, if placed under favourable circumstances, it can maintain its life by itself, and can perform all the actions proper to the species; and, consequently, the indefinite extension of the tree by the multiplication of buds is not in reality that exception to the rule just laid down, which it would appear to be. Precisely the same may be said in regard to the extension of a coral mass; for this is accomplished by the multiplication of polypes, by a process of budding from the original; and yet these remain connected with other, so as to form a compound whole, bearing a strong analogy to a tree. The same cannot be said, however, of the extension of a sea-weed, for this cannot be regarded as composed of a collection of distinct individuals; and we may therefore consider it as an illustration of the tendency to indefiniteness in point of *size*, which has been already pointed out in regard to *form*, as characteristic of the lower grades of organized structure, and as therefore leading us towards the inorganic world. Where this is the case, we find that the increase depends, as in Minerals, upon the multiplication of *similar* parts. Thus, in the sea-weed, each portion of the frond is almost a precise repetition of every other; and there is scarcely any of that mutual dependence among the different parts, which makes up our idea of one *individual*.

4. It is, however, in the internal arrangement or aggregation of the particles, respectively composing Organized structures and Inorganic masses, that we find the difference between the two most strongly marked. Every particle of a Mineral body (in which there has not been a *mixture* of ingredients) exhibits the same properties as those possessed by the whole; so that the chemist, in experimenting with any substance, cares not, except as a matter of convenience merely, whether a grain or a ton be the subject of his researches. The minutest atom of carbonate of lime, for instance, has all the properties of a crystal of this substance, were it as large as a mountain. Hence we are to regard a mineral body as made up of an indefinite number of constituent particles, similar to it and to each other in properties, and having no further relation among themselves than that which they derive from their juxtaposition. *Each particle*, then, may be considered as possessing a *separate individuality;* as we can predicate of its properties all that can be said of the largest mass. The organized structure, on the other hand, receives its designation from being made up of a number of distinct parts or *organs*, each of which has a tex-

ture or consistence peculiar to itself; and it derives its character from the whole of these collectively. Every one of these, as we shall hereafter see, is the instrument of a certain action or function, which it performs under certain conditions; and the concurrence of all these actions is required for the maintenance of the structure in its normal or regular state, and for the prevention or the reparation of those changes, which chemical and physical forces would otherwise speedily produce in it, from causes hereafter to be explained. Hence there is a relation of *mutual dependence* among the parts of an Organized structure; which is quite distinct from that of mere proximity. Thus, the perfect plant, which has roots, stem, and leaves, is an example of an organized structure, in which the relation of the different parts to the integrity of the whole is sufficiently obvious; since, when entirely deprived of either set of them, the plant must perish, unless it have within itself the power of replacing them.

5. In the lower animals, as in vegetables, we find a marked tendency to the repetition of *similar* parts, which shows an evident affinity to the mineral kingdom; and this not only in a composite tree, or in a coral mass, which, as just stated, must be considered as an aggregation of distinct individuals; but also in many animals, which cannot be divided without the destruction of their lives,—especially among the Radiated, and the lower Articulated tribes. Where such a repetition exists, *some* of the organs may be removed without permanent injury to the structure; their function being performed by those that remain. Thus, it is not uncommon to meet with specimens of the common five-rayed starfish, in which not only one or two, but even three or four, of the arms have been lost without the destruction of the animal's life; and this is the more remarkable, as the arms are not simply organs of locomotion or prehension, but contain prolongations of the stomach. In the bodies of the higher animals, however, where there are few or no such repetitions, and where there is consequently a greater diversity in character and function between the different organs, the mutual dependence of their actions upon one another is much greater, and the loss of a single part is much more likely to endanger the existence of the whole. Such structures are said to be more *highly organized* than those of the lower classes; not because the whole number of parts is greater,—for it is frequently much less; but because the number of *dissimilar* parts, and the consequent adaptation to a *variety* of purposes, is much greater, —the principle of division of labour, in fact, being carried much further, a much larger class of objects being attained, and a much greater perfection in the accomplishment of them being thus provided for.

6. Keeping in view, then, what has just been stated in regard to the divisibility of a Tree or a Zoophyte into a number of parts, each capable of maintaining its own existence, we may trace a certain gradation from the condition of the Mineral body to that of the highest Animal, in regard to the character in question. Thus the *individu-*

ality of a Mineral substance may be said to reside in each molecule; that of a Plant or Zoophyte, in each member; and that of one of the higher Animals, in the sum of all the organs. The distinction is much greater, however, between the lowest organized fabric and *any* mineral body, than it is between the highest and the lowest organized structures; for, as we shall hereafter see, the highest and most complicated may be regarded as made up of an assemblage of the lowest and simplest; whose structure and actions have been so modified as to render them mutually dependent; but which yet retain a separate individuality, such as enables them to continue performing their functions when separated from the mass, so long as the proper conditions are supplied.

7. Between the very simplest organized fabric, and every form of mineral matter, there is a marked difference in regard to *intimate structure* and *consistence*. Inorganic substances can scarcely be regarded as possessing a structure; since (if there be no admixture of components) they are uniform and *homogeneous* throughout, whether they be existing in the solid, liquid, or gaseous form; being composed of similar particles, held together by attractions which affect all alike. Far different is the character of Organized structures; for in the minutest parts of these may be detected a *heterogeneous* composition,—a mixture of solid and fluid elements, which are so intimately combined and arranged, as to impart such peculiarities to the tissues, even in regard to their physical properties, as we never encounter amongst Mineral bodies. In the latter, *solidity* or *hardness* may be looked upon as the characteristic condition; whilst in Organized structures, *softness* (resulting from the large proportion of fluid components) may be considered the distinctive quality, being most obvious in the parts that are most actively concerned in vital operations. This softness is evidently connected with the roundness of form characteristic of organized fabrics, which is most evident when the tissues contain the greatest proportion of fluid; whilst the plane surfaces and angular contours of mineral bodies are evidently due to the mode in which the solid particles are aggregated together, without any intervening spaces.

8. The greatest solidity exhibited by Organized fabrics is found where it is desired to impart to them the simple physical property of resistance; and this is attained by the deposition of solid particles, usually of a mineral character, in tissues that were originally soft and yielding. It is in this manner that the almost jelly-like substance, in which all the organs of animals originate, becomes condensed into cartilage, and that the cartilage is afterwards converted into bone; it is in the same manner, also, that the stones of fruit, and the heart-wood of timber-trees, are formed out of softer tissues. But, as we shall hereafter see, this kind of conversion, whilst it renders the tissue more solid and durable, cuts it off from any active participation in the vital operations; and thence reduces it to a state much more nearly analogous to that of mineral bodies. This resemblance is rendered

more close by the fact, that the earthy deposits frequently retain a distinctly crystaline condition; so that, when they are present in large proportion, they impart a more or less crystaline aspect to the mass, and especially a crystaline mode of fracture, which is evident enough in many shells. It must not be hence concluded, however, that such substances are of an inorganic nature; all that is shown by their crystaline structure being, that the animal basis exists in comparatively small amount, and that the mode in which the mineral matter was deposited has not interfered with its crystaline aggregation.

9. It is not to be disputed that a certain degree of homogeneity is apparently to be found in the *minutest* elements, into which certain organized tissues are to be resolved. Thus, in the *membranes* which form the walls of Animal and Vegetable *cells*, the highest powers of the microscope fail in detecting any such distinction of fluid and solid components, as that which has been described as characteristic of organized structures. Nevertheless it is indubitable that such distinct components *must* exist; and this especially from the properties of these membranes in regard to water. For it is one of the most remarkable facts in the whole range of science, that a membrane, in which not the slightest appearance of a pore can be discovered under the highest powers of the microscope, should be traversed by water; and that, too, with no inconsiderable rapidity. The change which these membranes undergo in drying is another proof that they are not so homogeneous as they appear, and that water is an element of their structure, not merely chemically, but mechanically. The same may be said in regard to the *fibres*, which form the apparently ultimate elements of the simple fibrous tissues in Animals, and which are also met with in the interior of certain cells and vessels in Plants. These fibres would appear to be of perfectly simple structure; yet we know from the loss of fluid, and the change of properties, which they undergo in drying, that water must have formed part of their substance.—It may be remarked, however, in regard to both these elementary forms of organized tissue, that the simplicity of their function is in complete conformity with the apparent homogeneousness of their structure; for the cell-membrane is chiefly destined to act, like the porous septum in certain forms of the voltaic battery, as a boundary-wall to the contained fluid, without altogether interfering with its passage elsewhere; the forces which produce its imbibition or expulsion being probably situated, not in this pervious wall, but in the cavity which it bounds. And, in the same manner, the function of the fibrous tissues, to which allusion was just now made, is of an entirely physical character; being simply to resist strain or pressure, and yet to allow of a certain degree of yielding by their elasticity.

10. In all cases in which active vital operations are going on, we can make a very obvious distinction of the structures subservient to them, into liquid and solid parts; and it is, indeed, by the continual reaction which is taking place between these, that the fabric is maintained in its normal condition. For, as we shall hereafter see, it is

liable to a constant decomposition or separation into its ultimate elements; and it is consequently necessary that the matters which have undergone that disintegration should be carried off, and that they should be replaced by new particles. These processes of removal and replacement, with the various actions subservient to them, make up a large proportion of the life of all Organized beings. Now as all the alimentary matter must be reduced to the liquid form, in order that it may be conveyed to the situations in which it is required, and as all the decomposed or disintegrated matter must be reduced to the same form in order to be carried off, the intermingling or mutual penetration of solids and liquids in the minutest parts of the body is at once accounted for. We shall hereafter see that a *cell*, or closed vesicle, formed of a membranous wall, and containing fluid, may be regarded as the simplest form of a living body, and the simplest independent part or instrument of the more complex fabrics (§ 30).

11. Organized structures are further distinguished from Inorganic masses, by the peculiarity of their *chemical constitution*. This peculiarity does not consist, however, in the presence of any elementary substances, which are not found elsewhere; for all the elements, of which organized bodies are composed, exist abundantly in the world around. It might have been supposed that beings endowed with such remarkable powers as those of Animals and Plants,—powers which depend, as we shall hereafter see, upon the exercise of properties to which we find nothing analogous in the Mineral world,—would have had an entirely different material constitution; but a little reflection will show, that the identity of the ultimate elements of Organized structures with those of the Inorganic world, is a necessary consequence of the mode in which the former are built up. For that which the parent communicates, in giving origin to a new being, is not so much the structure itself, as the power of forming that structure from the surrounding elements; and it is by gradually drawing to itself certain of these elements, that the germ becomes developed into the complete fabric. Now, of the *fifty-five* simple or elementary substances, which are known to occur in the Mineral world, only about *eighteen* or *nineteen* are found in Plants and Animals; and many of these in extremely minute proportion. Some of these appear to be merely introduced to answer certain chemical or mechanical purposes; and the composition of the parts which possess the highest vital endowments, is for the most part simpler and more uniform.

12. The actual *tissues* of Plants, when entirely freed from the substances they may contain, have been found to possess a very uniform composition, and to agree in their chemical properties. The substance which is left after the action, upon any kind of Vegetable tissue, of such solvents as are fitted to dissolve out the matters deposited in its cavities and interstices, is termed *Cellulose*. It consists of 24 Carbon, 21 Hydrogen, and 21 Oxygen; or, in other words, of Carbon united to the elements of water, in the proportion of eight of the former to seven of the latter. It may be very easily converted into gum or

sugar, by Chemical processes, which effect the removal or the addition of the elements of water. Now there is no compound known to exist in the Inorganic world, which bears the remotest analogy to this; and we have no reason to believe that it could be produced in any other way, than by that peculiar combination of forces which exists in the growing Plant.

13. In like manner, a large proportion of the Animal tissues, especially those most actively engaged in the operations of nutrition, have a nearly uniform composition, when freed from the substances they contain. We may distinguish among them two chief *proximate principles*, which appear under various modifications in a great variety of dissimilar parts, and which seem capable of conversion into other principles by the addition or subtraction of some of their constituents. The first and most important of these, named *Proteine*, consists of 40 Carbon, 31 Hydrogen, 5 Nitrogen, and 12 Oxygen; and although its composition is so complex, it appears to act like a simple body, in uniting with Oxygen, Acids, &c., in definite proportions, as well as with Sulphur and Phosphorus;—with which last, indeed, it is always found combined, in the Albumen, Fibrin, &c., that are commonly regarded as the organic constituents of the Animal tissues. The second of the chief proximate principles, termed *Gelatine*, is largely diffused through the Animal body; but there is much uncertainty whether it exists in a condition that can be properly termed organized, or whether it is a mere deposit, possessing a definite form, like many of the deposits in the Vegetable tissues. It consists of 13 Carbon, 10 Hydrogen, 2 Nitrogen, and 5 Oxygen; and it is principally characterized by its solubility in hot water, and by the insolubility of its compound with tannic acid.

14. We shall hereafter dwell more in detail upon the Chemical Constitution of the Animal tissues and products (Chap. III). These substances are only noticed here, in illustration of the general statement, that the proximate principles of Animal and Vegetable bodies,—that is, the simplest forms to which their component structures can be reduced, without altogether separating them into their ultimate elements,—are of extremely peculiar constitution; being made up of three elements in Plants, or four in Animals; of which the atoms do not seem to be united two by two, or by the method of *binary* composition; but of which a large number are brought together to form one *compound atom*, of *ternary* or *quaternary* composition. This compound atom, like Cyanogen, and many others derived from Organic products, acts like a simple or elementary one in its combinations with other substances. It is worthy of remark that, in this respect as in others, the Vegetable kingdom is intermediate between the Animal and the Mineral. For the two bases of the Animal tissues, whose composition has been just given, are remarkable not only for containing *four* elements, but for the very large number of atoms of each which enter into the single compound atom of the Proteine or Gelatine; and the proportions of these elements to each other are not

such, as to lead to the suspicion that the compound atom may be regarded as made up of simpler ones, united together in the manner of the acids and bases of Inorganic Chemistry. On the other hand, the Cellulose of Plants is much simpler in its composition, since it includes only three elements, and the numbers which represent their proportions are smaller; whilst these proportions are themselves such, as suggest the idea of simplicity in their method of combination,—the union of water and carbon in the common binary method. This idea is confirmed by the mode of the original production of cellulose, which indicates a direct union of carbon with water; as well as by the fact, that the chemical difference between cellulose and numerous other substances found in Plants, may be represented by the simple addition or subtraction of a certain number of atoms of water; and that the chemist can effect an actual conversion of the former into certain of the latter, by means which are calculated to effect such an addition or subtraction.

15. We shall hereafter see that Vegetables are intermediate between the Animal kingdom and the Inorganic world in another most important particular—the nature of the Chemical operations they effect; for, although their own *organized tissues* uniformly have the composition of Cellulose, they nevertheless have the power of secreting and storing up, in the interstices of these tissues, compounds which are nearly or exactly identical with animal Proteine in composition and properties: and they derive the materials for these compounds—the quaternary as well as the ternary—directly from the Inorganic world; being endowed with the wonderful power of elaborating them from the carbonic acid, water, and ammonia, supplied by the atmosphere and by the soil in which they are implanted. On the other hand, Animals possess no such power; they are entirely dependent upon Plants for their alimentary materials; and they employ for the building-up of their own structures, not the *tissues* of Plants, but the substances secreted by them.

2. *Of Vital Actions.*

16. We are now arrived at the second head of our inquiry,—namely the nature of those *actions*, which distinguish living beings from masses of inert matter, and which are designated as *Vital*, to point out their distinctness from Physical and Chemical phenomena. There can be no doubt whatever, that, of the many changes which take place during the *life*, or state of *vital activity*, of an Organized being, and which intervene between its first development and its final decay, a large proportion are effected by the agency of those forces, which operate in the Inorganic world; and there is no necessity whatever for the supposition, that these forces have any other operation in the living body than they would have *out* of it under similar circumstances. Thus the propulsion of the blood by the heart through the large vessels, is a phenomenon precisely analogous

to the propulsion of any other liquid through a system of pipes by means of a forcing pump; and if the arrangement of the tubes, the elasticity of their walls, the contractile power of the heart, and the physical properties of the fluid, could be precisely imitated, the artificial apparatus would give us an exact representation of the actions of the real one. The motor force of the muscles upon the bones, again, operates in a mode that might be precisely represented by an arrangement of cords and levers; the peculiarity here, as in the former case, being solely in the mode in which the force is first generated. So, again, the digestive operations which take place in the stomach are capable of being closely imitated in the laboratory of the chemist: when the same solvent fluid is employed, and the same agencies of heat, motion, &c., are brought into play. Moreover we shall hereafter see reason to believe, that the peculiar form of Capillary Attraction, to which the term Endosmose is applied, performs an important part in the changes which are continually taking place in the living body.

17. But after every possible allowance is made for the operation of Physical and Chemical forces, in the living Organism, there still remain a large number of phenomena, which cannot be in the least explained by them, and which we can only investigate with success, when we regard them as resulting from the agency of forces as distinct from those of Physics and Chemistry, as *they* are from each other. It is to these phenomena that we give the name of *Vital;* the forces from whose operation we assume them to result, are termed *vital forces;* and the properties, which we must attribute to the substances exerting those forces, are termed *vital properties*. Thus we say that the *act of contraction* in a Muscle is a *vital phenomenon;* because its character appears totally distinct from that of a Physical or Chemical action; and because it is dependent upon other vital changes in the muscular substance. The act is the manifestation of a certain *force*, the possession of which is peculiar to the muscular structure, and which is named the *Contractile force*. Further, that force may remain (as it were) dormant in the muscular structure, not manifesting itself for a great length of time, and yet capable of being called into operation at any moment; and this dormant force is termed a *property;* thus we regard it as the essential peculiarity of living Muscular tissue, that it possesses the vital property of *Contractility*. Or, to reverse the order, the muscle is said to possess the property of Contractility; the property called into operation by the appropriate stimulus gives rise to the Contractile Force; and the Force produces, if its operation be unopposed, the act of Contraction.

18. It may be said that the distinction here made is a verbal one; and that a very simple thing is thus made complex: but it will be presently seen that it is necessary, in order to enable us to take correct views of the nature of Vital phenomena, and to understand their analogies with those of the Inorganic world. And, in fact, the distinction between the *property*, the *force*, and the *action*, becomes ap-

parent upon a little consideration. Of the property we are altogether unconscious, so long as it is not called into exercise; we could not, for example, determine by the simple exercise of any of our senses, whether a certain piece of muscle retained, or had lost its contractility. When the property is called into action by its appropriate stimulus, we may convince ourselves that a force is generated, even if no sensible action is prevented; thus, if we were to hold the two extremities of a muscle so firmly, as to prevent them from approximating in the least degree when its contractility was excited, we should be conscious of a powerful force tending to draw our hands together; and we might measure the amount of that force, by mechanical means adapted to determine the weight it would sustain. And lastly, if no obstacle be interposed to the act of Contraction, it then becomes obvious to our senses, by the change in the shape of the muscle, and by the approximation of its two extremities, as well as of the bodies to which they are attached.

19. The advantage of this method of viewing the phenomena of Life is best shown, by turning our attention for a moment to the mode of investigation practised in Physics and Chemistry. Thus, when a stone falls towards the earth, we say that this is an *act* or phenomenon of Gravitation. The force with which the stone tends to fall to the ground, whether it actually falls or not, is called the *force* of Gravitation; and the property, by the exercise of which that force is generated, is called the *property* of Gravitation. Now, from observation of the moon's motion it is shown that *she* too descends towards the earth by an act of Gravitation; and that she does so with a certain force, which, acting in conjunction with her tangential or centrifugal force, produces her movement in an elliptical orbit round the earth; which force is the result of the exercise of her property of Gravitation. Could we conceive the Earth to be withdrawn, or annihilated, the *property* of Gravitation would still exist in the stone, or in the Moon's mass; but the *force* would be extinct, for want of the excitement of the property; and the action would consequently not take place.—Now, it may be further established from Astronomical observation, that not only does the Moon gravitate towards the Earth, but the Earth gravitates towards the Moon; so that, if the two bodies were entirely free from the action of all other forces, they would fall towards each other (the distance traversed by each being in proportion to the size of the other), and would meet in their common centre of Gravity. Hence it is evident that the attractive force is similar in both bodies; and our idea of the property of Gravitation must be extended, therefore, from the Earth to the Moon. Again, we find ample reason to believe that the same force acts between the Sun and the Planets,—between the Planets and the Sun,—and amongst the Planets themselves; and further, careful experiment shows that masses of matter upon the Earth's surface are not only attracted by it, and attract it in their turn, but that they attract and are attracted by each other. Hence we arrive at the idea of the *univer-*

sality of this property of mutual attraction; and we perceive that, in spite of the varieties in the actions it produces, and of the differences in the amounts of the forces to which it gives rise, the *property* is the same throughout; so that we can predict all these actions, and anticipate the forces which will be developed, from the simple general expression of the property of Mutual Attraction, and of the conditions according to which it operates,—constituting the *Law* of Gravitation or Mutual Attraction.

20. Now in this case of Mutual Attraction, we have no opportunity of witnessing the dormant condition of the property in any mass of matter; for, as nothing is wanting but the presence of another mass to call this property into operation, it is *always* generating force, and giving rise to actions. If we could conceive of the existence of but a single mass of matter in the universe, we shall at once see that, though possessed of the property of mutual attraction, it would not be able to exercise it so as to generate an attractive force, or to produce a movement.

21. But we will turn to another case; in which there is a closer analogy to the condition of living beings; and by which, therefore, the view here put forth may be more clearly illustrated. When a magnet (itself a bar of iron, having no peculiarity of appearance), draws towards it a piece of iron, we may say that a *Magnetic action* or phenomenon takes place; further, we speak of the power which produces the movement, as the *Magnetic force;* and we attribute this force to a certain property inherent in the Magnet, by virtue of which it draws towards itself all pieces of iron that are within the sphere of its operation,—and we speak of the iron bar as endowed with the *property* of *Magnetic attraction*. Now we cannot ascertain the presence or absence of this property in a certain bar of iron, by any difference in its aspect, its specific gravity, its chemical properties, nor, in fact, by any other mode than the putting it in circumstances adapted to call the Magnetic property into action if it really exist; thus we dip it into iron filings, and judge by their adhesion whether it is capable of attracting them; or, as a still more delicate test, we ascertain whether it is capable of exerting any repulsive power on a delicately-suspended needle already magnetized. Again, a needle, or bar of iron, which exhibits this magnetic power of attracting other portions of the same metal, exhibits another power which would seem at first sight totally distinct; namely, that of constantly turning one of its extremities towards the north, and the other towards the south, when it is so supported as to be free to do so. And yet there is no doubt whatever, that this directing power is only another manifestation of the same *magnetic attractiveness;* depending on the relation between the magnetized bar, or needle, and the Earth, which must itself be regarded as a great magnet. Hence the idea of a peculiar kind of mutual attractiveness,—existing in a limited class only of bodies, capable of being excited in one by a certain agency on the part of the

other,*—and requiring for its exercise or manifestation a certain set of conditions, without which no phenomenon results,—is that which we regard as fundamental in the Science of Magnetism.

22. We may now turn from these departments of Physical Science to Chemistry; and here we shall find that the investigation is carried on upon the very same plan. In fact, the whole science of Chemistry is founded upon the idea of a certain attractiveness or *affinity* existing among the *ultimate particles* or molecules of the *different* elementary substances; and therefore entirely distinct from the homogeneous attraction which holds together the particles of the same mass, or from the gravitative attraction, which operates alike upon all masses, whatever be their composition. Thus we say that Sulphuric acid and Potash have an *affinity* for each other; because they unite when they are brought together, and form a new compound. This is a *Chemical action* or phenomenon. Now we know that they tend to unite with a certain *force;* a force, however, which cannot be measured mechanically, and which can only be expressed by comparing it with some other force of the same kind. Thus we say that the mutual affinity of Sulphuric acid and Potash is greater than that of Nitric acid and Potash; because, if we pour Sulphuric acid upon Nitrate of Potash, the Sulphuric acid detaches (as it were) the Potash from its connection with the Nitric acid, forms a new compound with it, and sets the Nitric acid free. Hence we say that it is a property of Sulphuric acid to have a very strong affinity for Potash. This property exists in every particle of Sulphuric acid that exists, whether free or combined; but it remains dormant, until it is called into operation by the contact of Potash; and it then develops a force, which may completely change the combinations previously existing, and give rise to new ones.

23. Now of this property we are not informed by any of the other properties of Sulphuric acid; and we only recognize its existence by the action which is the result of its exercise. If a new element or compound be discovered, the chemist is totally unable to predict its force of affinity for this or that substance; and he can only guess by analogy, what will be its behaviour under various circumstances. Thus if it have the external properties of a Metal, he presumes that it will correspond with the Metals in possessing a strong affinity for oxygen, sulphur, &c.; whilst if it seem analogous to Iodine, Chlorine, &c., he infers that it will be a supporter of combustion, that it will form an acid with hydrogen, and so on. But even though such guesses may be made with a certain amount of probability, nothing but experience can show the positive degrees of affinity, which the substance may have for others of different kinds; and the experimental determination can only be made by observing the *actions* of the body when placed in different circumstances, from which we judge of its *pro-*

* As when one magnet is *made* by another; or when iron rails, pokers, &c., become magnetic by the influence of the earth.

perties, and of the *forces* to which these properties give rise when they are called into operation.

24. It is hoped that the propriety of the distinct use of the terms *vital action*, *vital force*, and *vital property*, will now be evident; and that the student will be now prepared to attach distinct ideas to each of them. It is the business of the Physiologist to study those actions or phenomena which are peculiar to living beings, and which are hence termed *vital;* he endeavours to trace them to the operation of the fundamental properties of organized structures—just as the Astronomer traces all the movements, regular and perturbed, of the heavenly bodies to the mutual attraction of their masses, acting concurrently with their force of onward rectilinear movement; or as the Chemist attributes the different acts of combination or separation, which it is his province to study, to the mutual affinities of the substances concerned: and the physiologist, like the astronomer or the chemist, seeks to determine the laws according to which these properties act, or, in other words, to express the precise conditions under which they are called into play, and the forces which they then generate. It is only in this manner, that Physiology can be rightly studied and brought to the level of other sciences. There can be no doubt that its progress has been greatly retarded by the assumption that its phenomena were all to be attributed to the operation of some general controlling agency, or Vital Principle; and that the laws expressing the conditions of these phenomena must be sought for by methods of investigation entirely distinct from those which are employed in other sciences. But a better spirit is now abroad; and the student cannot be too strongly urged to discard any ideas of this kind as absolutely untenable; and to keep steadfastly in view, that the laws of Vital Action are to be attained in the same manner as those of Physics or Chemistry,—that is, by the careful collection and comparison of vital phenomena, and by applying to them the same method of reasoning, as that which is used in determining the forces and properties on which other phenomena depend. True it is, that we can scarcely yet hope to reach the same degree of simplification, as that of which other sciences are capable; and this on account of the very complex nature of the phenomena themselves, and the difficulty of satisfactorily determining their conditions. The uncertainty of the results of Physiological experiments is almost proverbial; that uncertainty does not result, however, from any want of fixity in the conditions under which the vital properties operate, but merely from the influence of differences in those conditions, apparently so slight as to elude observation, and yet sufficiently powerful to produce an entire change in the result. And, owing to that mutual dependence of the different actions of the organized structure, to which reference has been already made (§ 5), we cannot seriously derange one class of these actions, without also deranging, or even suspending others;—a circumstance which obviously renders vital phenomena much more difficult of investigation than those of inorganic matter.

25. All sciences have their "ultimate facts;" that is, facts for which no other cause can be assigned than the Will of the Creator. Thus, in physics, we cannot ascend above the fact of Attraction (which operates according to a simple and universal law) between all masses of matter; and in chemistry, we cannot rise beyond the fact of Affinity (limited by certain conditions which are not yet well understood) between the particles of different kinds of matter. When we say that we have *explained* any phenomenon, we merely imply that we have traced its origin to these properties, and shown that it is a necessary result of the laws according to which they operate. For the existence of the properties, and the determination of the conditions, we can give no other reason than that the Creator *willed* them so to be; and, in looking at the vast variety of phenomena to which they give rise, we cannot avoid being struck with the general harmony that exists amongst them, and the mutual dependence and adaptation that may be traced between them, when they are considered as portions of the general economy of Nature.—There is no difference in this respect between Physiology and other sciences; except that the number of these (apparently) ultimate facts is at present greater in physiology, than it is in other sciences, because we are not at present able to include them under any more general expression. Thus we find a certain peculiar endowment existing in one form of structure; and another endowment, equally peculiar, inherent in another; but we can give no reason why the structure called muscular, should possess contractility, and why the structure called nervous should be capable of generating and conveying the force which excites that contractility to action. Each of these facts, therefore, is for the present the limit to our knowledge; we can ascertain the conditions, according to which the muscular contractility, and the exciting power of the nerve, are called into operation, and can form some estimate of the amount of the forces which they generate; but we cannot see clearly that they are necessarily connected by any common tie, such as that which binds together the planetary masses, at the same time that it weighs down the bodies on the surface of the earth towards its centre.

26. The present condition of Physiology, however, finds its parallel in the history of some other sciences, in which there was an equal number of such facts that were for a time regarded as ultimate. Thus, until the phenomena of Terrestrial Magnetism had been investigated, the polar direction of the magnetic needle, its dip, and its variation, were regarded as phenomena altogether distinct from the phenomena of attraction and repulsion which are exhibited between two magnets; and the former seemed "ultimate facts," of which no further account could be given. So, also, before the time of Newton, the movements of celestial and terrestrial bodies were supposed to be entirely destitute of connection with each other. But, as the knowledge of the Earth's Magnetism has shown that the direction, variation, and dip of the compass are referable to the very polar forces which show

themselves on a small scale when two magnets are brought near each other; and as the mutual attraction of the earth and moon, of the sun and planets, has been shown to result from the same property, as that which draws together any two masses that are freely suspended; so may it be fairly anticipated that an increased attention to vital phenomena, and a more philosophical method of reasoning upon them, will tend towards the same kind of generalization, and, therefore, to the simplification of the principles of the science.

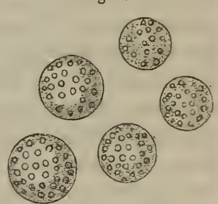
27. To satisfy ourselves—as some have done—with attributing the phenomena of Life to the agency of a "Vital Principle," is certainly a very easy way of extricating ourselves from the difficult path of physiological inquiry. But we are not in that manner conducted one step nearer to the object of that inquiry. For it is just as if, after the manner of the Ancients, we were to attribute the movements of the heavenly bodies to a "principle of motion," without inquiring into the conditions according to which it acts. Now, as Modern Physics show that all these varied movements (so different in kind, that no two of the heavenly bodies move at the same rate, or in paths of similar curvature), are the results of two forces, each acting according to its own laws, and modifying the other; and as it refers these forces to the exercise of simple properties of matter; so should the Physiologist seek for the common sources of the phenomena he witnesses, and for the properties of the organized structures, by the exercise of which they are produced. These properties do not differ more from those which he elsewhere encounters, than organized fabrics differ from masses of inorganic matter, both in structure and composition; and there is no necessity, therefore, to call in the aid of any other agency, to account for the peculiar endowments of those fabrics.

28. The advocates of the existence of a separate Vital Principle, as the unknown cause of the phenomena of life, rely much upon the peculiar adaptation, which may be observed amongst the several actions of an organized being; and upon their common subserviency to the maintenance of the integrity of the structure, and to the reparation of the effects of disease or injury, which imparts to them a character of *unity* that seems to be wanting elsewhere. But if we take a general survey of the phenomena of the universe at large, we shall find the adaptation just as complete, the mutual dependence as close, the unity of the whole as perfect. And as the Philosopher can do nought else than attribute this harmony, this mutual adaptation and dependence, this unity of purpose, in the phenomena of the *Macrocosm* or Universe, to the Infinite Wisdom and Power of the Designing Mind, so must he depart from all right methods of reasoning, to suppose that the like harmony, adaptation, and unity in the operations of the *Microcosm*, or little world in his own body, can have any other source.

29. The only sense in which the term "Vital Principle" can be properly used, is as a convenient and concise expression for the sum

total (so to speak) of the powers which are developed by the action of the Vital properties of Organized structures—these being not yet fully understood, and the conditions of their action being but imperfectly known. In this manner it has been customary to talk of the principles of Gravity, of Electricity, of Magnetism, &c., as the unknown causes of certain phenomena, which seemed to be connected by the same general conditions; but as the advance of Physical science has done away with these modes of expression, by referring all the phenomena to the simple properties of matter, and by fixing the conditions under which they occur, so should we aim at a corresponding simplification and precision in Physiology. The use of a term like Vital Principle, even in the restricted sense now specified, is attended with this danger:—that it rather checks inquiry, by giving rise to the idea that a reference to the agency of such a principle is alone sufficient to explain the phenomena; and, as it is attended with no corresponding advantage, it seems preferable to discard the term altogether. It will not be again introduced, therefore, in this Treatise; the object of which is to place the student in possession of what has been ascertained regarding the peculiar or vital properties of Organized Tissues. This may be most advantageously effected, by first making him acquainted with the general history of the series of phenomena exhibited by Living Beings of the simplest character, and by then tracing these phenomena, so far as possible, to their hidden sources. For this purpose we must have recourse to the simplest forms of Cryptogamic Plants, which consist of mere aggregations of *cells*, every one of which may be regarded as a distinct individual, since it is perfectly independent of the rest, and performs *for* and *by* itself, all the functions of Growth and Reproduction. We shall find, then, in the operations of the simple cell, an *epitome*, as it were, of those of the highest and most complex Plant; whilst those of the higher Plants bear a close correspondence with those which are immediately concerned in the Nutrition and Reproduction of the Animal body. The functions peculiar to Animals, and distinguishing them from Plants, must be separately considered.

Fig. 1.



Simple isolated cells, containing reproductive molecules.

30. A *Cell*, in Physiological language, is a closed vesicle or minute bag, formed by a membrane, in which no definite structure can be discerned, and having a cavity, which may contain matters of variable consistence. Such a cell constitutes the whole organism of such simple plants as the *Protococcus vivalis* (Red Snow), or *Palmella cruenta* (Gory Dew); for although the patches of this kind of vegetation which attract our notice, are made up of vast aggregations of such cells, yet they have no dependence upon one another, and the actions of each are an exact repetition of those of the rest. In such a cell, every organized fabric, however complex, originates. The

vast *tree*, almost a forest in itself, and the feeling, thinking, intelligent *man*, spring from a germ, that differs in no obvious particular from the permanent condition of one of these lowly beings. But whilst the powers of the latter are restricted, as we shall see, to the continual multiplication of new and distinct individuals like itself, those of the former enable it to produce new cells that remain in closer connection with each other; and these are gradually converted, by various transformations of their own, into the diversified elements of a complex fabric. The most highly organized being, however, will be shown to consist in great part of cells that have undergone no such transformation, amongst which the different functions performed by the individual in the case just cited, are distributed, as it were; so that each cell has its particular object in the general economy, whilst the history of its own life is essentially the same as if it were maintaining a separate existence.

31. We shall now examine, then, the history of the solitary cell of the Red Snow, or of any other equally simple plant, from its first development to its final decay; in other words, we shall note those Vital Phenomena, which are as distinct from those of any inorganic body, as is its organized structure (simple as it appears) from the mere aggregation of particles in the inert mass. In the first place, the cell takes its origin from a *germ*, which is a minute *molecule*, that cannot be seen without a microscope of high power. This molecule appears, in its earliest condition, to be a simple homogeneous particle, of spherical form; but it gradually increases in size; and a distinction becomes apparent between its transparent exterior and its coloured interior. Thus we have the first indication of the *cell-wall*, and the *cavity*. As the enlargement proceeds, the distinction becomes more obvious; the cell-wall is seen to be of extreme tenuity and perfectly transparent, and to be homogeneous in its texture; whilst the contents of the cavity are distinguished by their colour, which is bright-red in the species just mentioned, but more commonly green. At first they, too, seem to be homogeneous; but a finely granular appearance is then perceptible; and a change gradually takes place, which seems to consist in the aggregation of the minute granules into molecules of more distinguishable size and form. These molecules, which are the germs of new cells, seem to be at first attached to the wall of the parent-cell; afterwards they separate from it and move about in its cavity; and at a later period, the parent-cell bursts and sets them free. Now, this is the termination of the life of the parent-cell; but the commencement of a life of a new generation; since every one of these germs may become developed into a cell, after precisely the foregoing manner, and will then in its turn propagate its kind by a similar process.

32. By reasoning upon the foregoing history, we may arrive at certain conclusions, which will be found equally applicable to all living beings. In the first place, the cell originates in a germ or reproductive molecule, which has been prepared by another similar cell that

previously existed. There is no sufficient reason to believe, that there is any exception to this rule. So far as we at present know, every Plant and every Animal is the offspring of a parent, to which it bears a resemblance in all essential particulars; and the same may be said of the individual cells, of which the Animal and Vegetable fabrics are composed. But how does this *germ*, this apparently homogeneous molecule, become a Cell? The answer to this is only to be found in its peculiar property of drawing materials to itself from the elements around, and of incorporating these with its own substance. The Vegetable cell may grow wherever it can obtain a supply of Water and Carbonic acid; for these compounds supply it with Oxygen, Hydrogen, and Carbon, in the state most adapted for the exercise of the combining power, by which it converts them into that new compound, whose properties adapt it to become part of the growing organized fabric. Here, then, we have two distinct operations;—the union of the Oxygen, Hydrogen and Carbon, into that gummy or starchy product, which seems to be the immediate *pabulum* of the Vegetable tissues;—and the incorporation of that product with the substance of the germ itself.

33. The *first* of these changes *may be*, and probably *is*, of a purely *Chemical* nature; and analogous cases are not wanting, in the phenomena of Inorganic Chemistry, in which one body, A, exerts an influence upon two other bodies, B and C, so as to occasion their separation or their union, without itself undergoing any change. Thus Platinum, in a finely-divided state, will cause the union of Oxygen and Hydrogen at ordinary temperatures; and finely-powdered Glass will do the same at the temperature of 572°. This kind of action is called Catalysis. A closer resemblance, perhaps, is presented by the act of *fermentation;* in which a new arrangement of particles takes place in a certain compound, by the presence of another body which is itself undergoing change, but which does not communicate any of its elements to the new products. Thus, if a small portion of animal membrane, in a certain stage of decomposition, be placed in a solution of sugar, it will occasion a new arrangement of its elements, which will generate two new products, alcohol and carbonic acid. If the decomposition of the membrane have proceeded further, a different product will result; for instead of alcohol, lactic acid will be generated. There appears no improbability, then, in the idea, that the influence exerted by the germinal molecule is of an analogous nature; and that it operates upon the elements of the surrounding water and carbonic acid, according to purely Chemical laws, uniting the Carbon with the elements of Water, and setting free the Oxygen. This result of the nutritive operations of the simple cellular plants may be easily verified experimentally, by exposing the green scum, which floats upon ponds, ditches, &c., and which consists of the cells of a minute Cryptogamic Plant, to the influence of light and warmth beneath a receiver; it is found that oxygen is then liberated, by the decomposition of the carbonic acid contained in the water.

We shall presently have to return to the consideration of the Chemical phenomena of living beings; and shall pass on, therefore, to consider those to which no such explanation applies.

34. The *second* stage in the nutritive process consists in the appropriation of the new product thus generated to the enlargement of the living cell-structure;—a phenomenon obviously distinct from the preceding. It is well to observe, that this process, which constitutes the act of *organization*, may be clearly distinguished in the higher Plants and Animals, as consisting of two stages; the first of these being the further preparation or elaboration of the fluid matter, by certain alterations whose nature is not yet clear, so as to render it *organizable*, or fit to undergo organization; the second being the act of organization itself, or the conversion of the organizable matter into the solid texture, and the development in it of the properties that distinguish that texture. Thus, for example, we do not find that a solution of dextrin (or starch-gum) is capable of being at once applied to the development of vegetable tissue, although it is identical in composition with cellulose; for it must first pass through a stage, in which it possesses a peculiar glutinous character, and exhibits a tendency to spontaneous coagulation, that seems like an attempt at the production of organic forms. And in like manner the albumen of Animals is evidently not capable of being applied to the nutrition of the fabric, until it has been first converted into fibrin; which also is distinguished by its tenacious character, by its spontaneous coagulability, and by the fibrous structure of the clot. Now, in both these cases, there is probably some slight modification in Chemical composition, that is, in the proportions of the ultimate elements; but the *principal* alteration is evidently that which is effected by the re-arrangement of the constituent particles; so that, without any considerable change in their proportions, a compound of a very different nature is generated. Of the possibility of such changes, we have abundant illustrations in ordinary Chemical phenomena; for there is a large class of substances, termed *isomeric*, which, with an identical composition, possess chemical and physical properties of a most diverse character.

35. But we cannot attribute the production of Fibrin from Albumen, the organizable from the unorganizable material, to the simple operation of the same agencies as those which determine the production of the different isomeric compounds; for the properties of Fibrin are much more *vitally* distinct from those of Albumen, than they are either *chemically* or *physically;* that is, we find in the one an incipient manifestation of *Life*, of which the other shows no indications. The spontaneous coagulation of fibrin, which takes place very soon after it has been withdrawn from the vessels of the living body, is a phenomenon to which nothing analogous can be found elsewhere; for it has been clearly shown not to be occasioned by any mere physical or chemical change in its constitution; and it takes place in a manner which indicates that a new arrangement of particles has taken place in it, preparatory to its being converted into a living solid. For

this coagulation is not the mere homogeneous *setting*, which takes place in a solution of gelatine in cooling, nor is it the aggregation of particles in a mere granular state, (closely resembling that of a chemical precipitate), which takes place in the coagulation of albumen: it is the actual production of a simple *fibrous tissue*, by the union of the particles of fibrin in a determinate manner, bearing a close resemblance to the similar process in the living body (§ 188). We say, then, that the coagulation of Fibrin, and the production of a fibrous tissue, are the result of its *vital* properties, rather than of chemical or physical agencies; because no substance is known to perform any such actions, without having been subjected to the influence of a living body; and because the actions themselves are altogether different from any which we witness elsewhere. This production of an *organizable* or partially *vitalized* substance, from an unorganizable one, possessing none but chemical properties, and therefore as yet *inert*, so far as the living body is concerned, may be termed *Assimilation;* and it may be conceived, as we have seen, to consist of *a new arrangement* of the particles of the substance thus changed, *analogous* to that which occurs when one isomeric product is converted into another by some ordinary chemical agency,—Heat or Electricity for example; but *not identical* with it, because it cannot be produced by any other agency than that furnished by a *living* structure.

36. We now come to the act of Organization itself; which seems to consist of a continuation of the same kind of change,—that is, a new arrangement of the particles, producing substances which differ both as to structure and properties from the materials employed, but which may be so closely allied to them in chemical composition, that the difference cannot be detected. Thus, from the dextrin of plants is generated, in the process of cell-development, the cellulose which constitutes the walls of the cells: chemically speaking, there seems to be no essential distinction between these two substances; and yet between the living, growing, reproducing cell, and the inert, unchanging starch-grain, how wide the difference! So in the animal body, we find that the composition of the fibrin of muscular fibre scarcely differs, in regard to the proportion of its elements, from the fibrin, or even from the albumen, of the blood; and yet what an entire re-arrangement must take place in the particles of either, before a tissue so complex in structure, and so peculiar in properties, as muscular fibre, can be generated!

37. Both in the Plant and the Animal, we find that tissues presenting great diversities both in structure and properties, may take their origin in the same organizable material; but in every case (at least in the ordinary processes of growth and separation) the new tissue of each kind is formed *in continuity* with that previously existing. Thus in the stem of a growing tree, from the very same glutinous sap or cambium, intervening between the wood and the bark, the wood generates, in contact with its last-formed layer, a new cylinder of wood; whilst the bark produces, in contact with *its* last-formed layer, a new

cylinder of bark,—the woody cylinder being characterized by the predominance of ligneous fibre and ducts, and the cortical by the predominance of cellular tissue. In like manner we find that, in animals, muscle produces muscle, bone generates bone, nerve develops nerve in continuity with it,—all at the expense of the materials supplied by the very same blood. The *Nutrition* of tissues, by the organization of the materials contained in the nutrient fluid with which they are supplied, may be superficially compared therefore to the act of crystalization, when it takes place in a mixed solution of two or more salts. If in such a solution we place small crystals of the salts it contains, these crystals will progressively increase by their attraction for the other particles of the same kind, which were previously dissolved; each crystal attracting the particles of its own salt, and exerting no influence over the rest. But it must be borne in mind, that such a resemblance goes no further than the surface; for the growth of a crystal cannot be really regarded as in the least analogous to that of a cell. The crystal progressively increases by the deposit of particles upon its exterior; the interior undergoes no change; and whatever may be the size it ultimately attains, its properties remain precisely the same as those of the original nucleus. On the other hand, the cell grows from its original germ by a process of *interstitial* deposit; the substance of which its wall is composed, extends itself in every part; and the new matter is completely incorporated with the old.

38. Moreover, as the increase proceeds, we see an evident distinction between the cell-wall and its cavity; and we observe that the cavity is occupied by a peculiar matter, different from the substance of the cell-wall, though obviously introduced through it. Of the essential difference which may exist in composition, between the cell-wall and the contents of the cavity, we have a remarkable example in the case of the simple Cryptogamic plant, which constitutes Yeast, and which differs in no essential part of the history of its growth from the species already referred to. The substance of its cell-walls is nearly identical with ordinary Cellulose; whilst the contents of the cells are closely allied in composition to Protein, the material of many Animal tissues. Again, in the fat-cells of Animals, the cell-wall is formed from a protein compound; whilst the oily contents agree, in the absence of nitrogen, and in their general chemical relations, with the materials of the tissues of Plants. It is evident, then, that one of the inherent powers of the cell, is that by which it not only combines the surrounding materials into a substance adapted for the extension of its *wall*, but that which enables it to exercise a similar combining power on other materials derived from the same source, and to form a compound,—of an entirely different character, it may be,—which occupies its *cavity*. Now this process is as essential to our idea of a living cell, as is the growth of its wall; and it must never be left out of view, when considering the history of its development.

39. Every kind of cell has its own specific endowments; and generates in its interior a compound peculiar to itself. The nature of this compound is much less dependent upon the nutrient materials which are supplied to the cell, than upon the original inherent powers of the cell itself, derived from its germ. Thus we find that the Red Snow and Gory Dew invariably form a peculiar red secretion; and that they will only grow where they can obtain, from the air and moisture around, the elements of that secretion. Again, the Yeast Plant invariably forms a secretion analogous to animal protein; and it will only grow in a fluid which supplies it with the materials of that substance. Hence the Red Snow would not grow in a fermentible saccharine fluid; nor would the Yeast Plant vegetate on damp cold surfaces. Yet there is little difference, if any, between their cell-walls in regard to chemical composition.—So, also, we shall find hereafter, that one set of cells in the animal body will draw into themselves, during the process of growth, the elements of bile; another, the elements of milk; another, fatty matter, and so on;—the peculiar endowments of each being derived from their several germs, which seem to have an attraction for these substances respectively, and which thus draw them together; whilst the cell-wall appears to have a uniform composition in all instances.

40. The term *Secretion*, or setting-apart, is commonly applied to this operation, to distinguish it from Nutrition or growth; but it is obvious from what has now been stated, that the act of secretion is in reality the increase or growth of the cell-contents, just as the process of enlargement is the increase or growth of the cell-wall; and that the two together make up the whole process of Nutrition, which cannot be properly understood, unless both are taken into account. It is to be remembered, however, that the *contents* of the cell may not be destined to undergo organization; indeed we shall find hereafter, that the main use of certain cells is to draw off from the circulating fluid such materials as are incapable of organization; and the operation may be so far attributed, therefore, to the agency of Chemical forces. But we shall find that, in other instances, the cell-contents *are* destined to undergo organization, and this either within the parent-cell, or after they leave it; here, then, we must recognize a distinct vitalizing agency, as exerted by the cell upon its contents.

41. This organizing or vitalizing influence must be exerted upon a certain portion of the contents of every cell that is capable of reproducing itself; for it is in this manner that those germs are produced, in which all the wonderful properties are inherent, that are destined to manifest themselves, when they are set free from the parent-cell. This power of *Reproduction* is one of those, which most remarkably distinguishes the living being; and we shall find that, in the highest Animal, as in the humblest Plant, it essentially consists in the preparation of a cell-germ, which, when set free, gradually develops itself into a structure like that from which it sprang. The reproductive molecules or cell-germs are formed, like the tissue and the contents

of the parent-cell, from the nutrient materials which it has the power of bringing together and combining; and in their turn they pass through a corresponding series of changes; and at length produce a new generation of similar molecules, by which the race is destined to be continued. Notwithstanding the mystery which has been supposed to attach itself to this process, it is obvious that there is nothing in reality more difficult to understand in the fact that the parent-cell organizes and vitalizes the cellulose which it has elaborated, so that it should form the germ of a *new* individual possessing similar properties with itself, than in its incorporating the same material with *its own* structure, and causing it to take a share in its own actions.

42. Finally, the parent-cell having arrived at its full development, having passed through the whole series of changes which is characteristic of the species, and having prepared the germs by which the race is to be propagated, *dies* and *decays*;—that is, all those operations, which distinguish living organized structures from inert matter, cease to be performed; and it is subject to the influence of chemical forces only, which speedily occasion a separation of its elements, and cause them to return to their original forms, namely, water and carbonic acid. It must not be hence supposed, however, that there is anything peculiar in the forces which hold together those elements during the life of the cell, and that the operation of the ordinary chemical agencies is resisted by the superior power of vitality. On the contrary it is certain that *interstitial* death and decay are incessantly taking place during the whole life of the being; and that the maintenance of its healthy or normal condition depends upon the constant removal of the products of that decay, and upon their continual replacement. If, on the one hand, those products be retained, they act in the manner of poisons; being quite as injurious to the welfare of the body, as the most deleterious substances introduced from without. On the other hand, if they be duly carried off, but be not replaced, the conditions essential to vital action are not fulfilled, and the death of the whole must be the result.

43. Now it is to be observed that, as Plants obtain the materials of their *growth* from water and carbonic acid, taking the carbon from the latter and setting free the oxygen, so do they require, as the condition for their *decay*, the presence of oxygen, which may unite with the carbon that is to be given back to the atmosphere. If secluded from this, the vegetable tissues may be preserved for a long time without decomposition. Generally speaking, indeed, they are not prone to rapid decay, except at a high temperature; and hence it is that we have so little evidence, in Plants, of the constant interstitial change, of which mention has just been made. Its existence, however, (at least in all the softer portions of the structure,) is made evident by the fact, that a continual extrication of carbonic acid takes place, to an amount which sometimes nearly equals that of the carbonic acid decomposed, and of the oxygen set free, in the act of Nutrition (§ 33). The latter operation is only effected under the

stimulus of sun-light; the former is constantly going on, by day and by night, in sunshine and in shade; and if it be impeded or prevented by want of a due supply of oxygen, the plant speedily becomes unhealthy. Now this extrication of the products of interstitial decay is termed *Excretion.* It is usually confined in Plants to the formation of carbonic acid and water, by the union of the particles of their tissues with the oxygen of the air,—a process identical with that which occurs after the death of the entire structure. But in Animals it is much more complicated, owing to the larger number of constituents in their fabric, and to the much greater variety in the proportions in which these are combined; hence the products of interstitial decomposition are much more numerous and varied, and several distinct modes are devised for getting rid of them. Moreover, as the animal tissues are much further removed than the Vegetable from the composition of Inorganic bodies, they are subject to much more rapid and constant decay; and we shall find that this decay is so considerable in amount, as to require on the one hand a very complex excretory apparatus to carry off the disintegrated matter, and on the other a large supply of nutrient material to replace it.

44. The preceding history may be thus summed up.—1. The Vegetable cell-germ or reproductive molecule draws to itself, and combines together, certain inorganic elements; and thereby produces a new and peculiar compound. This compound, however, exhibits no properties that distinguish it from others, in which ordinary *Chemical* agencies have been concerned; and we may, therefore, regard the first act of the cell-germ as of a purely chemical nature. We shall presently see that chemical agencies are undoubtedly concerned in it, to a very considerable degree. The Animal cell-germ does not possess the same Chemical power; it is not capable of decomposing the water, carbonic acid, and ammonia, which include the elements of its tissues; and it is entirely dependent for its growth upon the supply of nutriment previously prepared for it by the agency of the vegetable kingdom, many species of which possess, as we have seen, the power of generating a protein compound within their cells, though they cannot organize it.—2. The cell-germ then exerts an agency upon the *pabulum* thus prepared; by which a new arrangement of its particles is produced. This new arrangement gives new and peculiar qualities to the fluid, which show that it is something more than a mere chemical compound, and that it is in the act of undergoing the process of organization.—3. The Organization of this elaborated pabulum then takes place: its materials are withdrawn from the fluid, and incorporated with the solid texture; and in thus becoming part of the organized fabric, they are caused to exhibit its own peculiar properties.—4. At the same time another portion of this pabulum is gradually prepared to serve as the germ of a new cell, or set of cells, by which the same properties are to be exhibited in another generation.—5. By a Chemical operation resembling that concerned in the first preparation of the pabulum, a certain secretion more or less differing from it in character, but not

destined to undergo organization, is formed in the cavity of the cell.—6. A decomposition or disintegration of the organized structure, is continually going on, by the separation of its elements into simpler forms, under the influence of purely Chemical agencies; and the setting free of these products by an act of excretion, is thus incessantly restoring to the inorganic world a portion of the elements that have been withdrawn from it.—7. When the term of life of the parent-cell has expired, and its reproductive molecules are prepared to continue the race, the actions of nutrition cease; those of decomposition go on unchecked; and the death of the structure, or the loss of its distinguishing vital properties, is the result. By the decomposition, which then takes place with increased rapidity, its elements are restored to the inorganic world; presenting the very same properties as they did when first withdrawn from it; and becoming capable of being again employed, by any successive numbers of living beings, to go through the same series of operations.

45. Thus, then, we see that our fundamental idea of the properties of the simplest living being consists in this:—that it has the capability of drawing into its own substance certain of the elements furnished by the inorganic world;—that it forms these into new combinations (which the Chemist may find out methods of imitating);—that it re-arranges the particles of these combinations, in that peculiar mode which we call organization;—that in producing this new arrangement it also calls forth or develops in them a new set of properties, which we call vital, and which are manifested by them, either as connected with the parent structure, or as appertaining to the germs of new structures, according to the mode in which the materials are applied;—that, notwithstanding its peculiar condition, it remains subject to the ordinary laws of Chemistry, and that decomposition of its structure is continually taking place;—and finally, that the duration of its vital activity is limited; the changes which the organic structure undergoes, in exhibiting its peculiar actions, being such as to render it (after a longer or shorter continuance of them) incapable of any longer performing them.

46. There is abundant evidence, that the duration of the *Life*, or state of *Vital Activity*, of an organized structure, is inversely proportioned to the degree of that activity; and consequently that Life is shortened by an increased or abnormal activity; whilst it may often be prolonged by influences which diminish that activity. Thus we shall hereafter find reason to believe, that the duration of life in the Muscular and Nervous tissues of Animals is entirely dependent upon the degree in which they are exercised; every call upon their activity causing the death and disintegration of a certain part; whilst if they be allowed to remain in repose for a time, only that amount of decomposition will take place to which their chemical character renders them liable. Again, we may trace the connection between the vital activity of a part and the duration of its life, by comparing the transitory existence of the *leaves* of a Plant, which are its active organs of nu-

trition with the comparative permanence of its woody *stem*, the parts of which, when once completely formed, undergo very little subsequent change. The most striking manifestation of this connection, however, is afforded by that condition in which, without any appreciable amount of vital activity or change, an organized structure may remain unaltered for centuries; not only presenting at the end of that time its original structure, but being prepared to go through its regular series of vital operations, as if these had never been interrupted. This state may be designated as *Dormant Vitality.* It differs, on the one hand, from *Life;* because life is a state of *Activity.* On the other hand, it differs from *Death;* because Death implies not merely a suspension of activity, but a total *loss of vital properties.* Now in the state of Dormant vitality, the vital properties are retained; but they are prevented from manifesting themselves by the want of the necessary conditions. When these conditions are supplied, the state of vital activity is resumed, and all the functions of life go on with energy.

47. Of this Dormant Vitality it may be well to adduce some examples; which may assist in impressing on the mind of the student the general views here put forth. This condition is manifested in the most remarkable manner by the seeds and germs of plants: many of which are adapted to remain, for an unlimited period, in a state of perfect repose, and yet to vegetate with the greatest activity, as soon as ever they are subjected to the necessary influence. Thus the sporules of the Fungi, which can only germinate in decaying organized matter, seem universally diffused through the atmosphere, and ready to vegetate with the most extraordinary rapidity, whenever a fitting opportunity presents itself. This at least appears to be the only feasible mode of explaining their appearance, in the forms of Mould, Mildew, &c., on all moist decaying substances; and that there is no improbability in the supposition itself, is shown by the excessive multiplication of these germs, a *single individual* producing not less than *ten millions* of them, so minute as when collected to be scarcely visible to the naked eye, rather resembling thin smoke, and so light as to be wafted by every movement of the atmosphere;—so that, in fact, it is difficult to imagine any place from which they can be excluded. Moreover it is certain that an equally tenacious vitality exists in the seeds of higher plants. Those of most species inhabiting temperate climates are adapted to remain dormant during the winter; and may be easily preserved, in dry air, and at a moderate temperature, for many years. Some of those which had been kept in the Herbarium of Tournefort during upwards of a century, were found to have preserved their fertility. Cases are of no unfrequent occurrence, in which ground that has been turned up, spontaneously produces plants dissimilar to any in their neighbourhood. There is no doubt that in some of these cases, the seed is conveyed by the wind, and becomes developed in spots which afford congenial soil,—as already remarked in the case of the Fungi. Thus it is commonly observed that clover

makes its appearance on soils which have been rendered alkaline by lime, by strewed wood-ashes, or by the burning of weeds. But there are many authentic facts, which can only be explained upon the supposition, that the seeds of the newly-appearing plants have lain for a long period imbedded in the soil, at such a distance from the surface as to prevent the access of air and moisture; and that, retaining their vitality under these circumstances, they have been excited to germination when at last exposed to the requisite conditions. Thus Professor Lindley states as a fact, that he has raised three raspberry-plants from seeds taken from the stomach of a man, whose skeleton was found thirty feet below the surface of the earth, at the bottom of a barrow which was opened near Dorchester; as his body had been buried with some coins of the Emperor Hadrian, there could be no doubt that the seeds were 1600 or 1700 years old. Again, there are undoubted instances of the germination of grains of wheat, which were inclosed in the wrappers of Egyptian mummies, perhaps twice that number of years ago; the wheat being different in some of its characters from that now growing in the country.

48. These facts make it evident, that there is really no limit to the duration of this condition; and that when a seed has been thus preserved for ten years, it may be for a hundred, a thousand, or ten thousand,—provided no change of circumstances either exposes it to decay, or calls its vital properties into activity. Hence in cases where seeds have been buried deep in the earth, not by human agency, but by some geological change, it is impossible to say how long anteriorly to the creation of man they may have been produced and buried,—as in the following very curious instance. Some well-diggers in a town on the Penobscot river, in the State of Maine (New England), about forty miles from the sea, came at the depth of about twenty feet upon a stratum of sand, which strongly excited curiosity and interest, from the circumstance that no similar sand was to be found anywhere in the neighbourhood, and that none like it was nearer than the sea-beach. As it was drawn up from the well, it was placed in a pile by itself; an unwillingness having been felt to mix it with the stones and gravel which were also drawn up. But when the work was about to be finished, and the pile of stones and gravel to be removed, it was necessary also to remove the sand-heap. This, therefore, was scattered about the spot on which it had been formed, and was for some time scarcely remembered. In a year or two, however, it was perceived that a large number of small trees had sprung from the ground over which the heap of sand had been strewn. These trees became in their turn objects of strong interest, and care was taken that no injury should come to them. At length it was ascertained that they were Beach-Plum trees; and they actually bore the Beach-Plum, which had never before been seen, except immediately upon the sea-shore. The trees had therefore sprung from seeds, which were in the stratum of sea-sand, that had been pierced by the well-diggers. By what convulsion they had been thrown there, or how long they had

quietly slept beneath the surface, cannot possibly be determined with exactness; but the enormous length of time that must have elapsed, since the stratum in which the seeds were buried formed part of the sea-shore, is evident from the accumulation of no less than twenty feet of vegetable mould upon it.

49. Numerous instances will be related in the succeeding Chapter, of the occurrence of a similar condition in fully-developed Plants, and even in animals of high organization. In some of these it is a regular part of the history of their lives, coming on periodically like sleep; whilst in others it is capable of being induced at any time, by a withdrawal of some of the conditions essential to vital activity. In regard to all of them, however, it may be observed, that the vitality can only be retained, when the organized structure itself is secluded from such influences as would produce its decay. Thus the hard dry tissue of the seed is but little liable to decomposition; and all that is usually required for the prevention of change in its structure, is seclusion from the free access of air and from moisture, and a steady low or moderate temperature. If a seed be exposed to air and moisture, but the temperature be not high enough to occasion its germination, it will gradually undergo decay, and will consequently lose its vitality. The animal tissues are more liable, as already mentioned, to spontaneous decomposition; and the only instances in which they can retain their vitality for a lengthened period, without any nutritive actions, are those in which all decomposition is prevented, either by the action of cold, or by the complete deprivation of air or of moisture—as when Frogs, Snakes, &c., have been preserved for years in an ice-house, or Wheel-Animalcules have been dried upon a slip of glass.

50. The class of phenomena last brought under notice, serves to exhibit in a very remarkable manner the dependence of all Vital Action, upon certain *other* conditions, than those furnished by the organized structure possessed of vital properties. Thus a seed does not germinate *of itself;* it requires the influence of certain external agents, such as warmth,—air, and moisture; and it can no more produce a plant without the operation of these, than warmth, air, and moisture could produce it of themselves. Hence these agents supply a set of conditions which are equally essential to vital action, with the properties of the organized structure itself; and as they excite those properties, or call them into activity, they are termed *Vital Stimuli.* Now we have in this fact a complete analogy with the phenomena which we may elsewhere notice. Thus, as already pointed out, the property of mutual attractiveness between masses of matter is only manifested, when more than one mass is present; and unless that condition be supplied, the property remains dormant. Or, again, the attractive property of a magnet is only manifested, when a piece of iron is brought into its proximity. We find still closer analogies in the phenomena of Chemistry; thus there are many chemical operations, which require a certain amount of heat as a necessary condition; and the heat may be justly said to be the stimulus to the

change. We find, indeed, that the amount of heat is even capable of subversing the relative affinities of two bodies for a third; and that thus two changes of an opposite character may be induced by the simple regulation of temperature. For example, at a white heat, the affinity of iron for oxygen is so much stronger than that of potassium, that, by placing iron in contact with potassa, the latter is decomposed, and the result is oxide of iron and potassium. At ordinary temperatures, on the other hand, the affinity of potassium for oxygen is much the stronger of the two; and if potassium and oxide of iron be then brought to act upon each other, the oxygen quits the latter, and restores the former to the condition of potassa. Hence we may justly say, that a particular temperature is the *stimulus* to each of these actions. In the same manner, the influence of light is concerned in producing a large number of chemical changes, including all those which are concerned in the formation of Photographic pictures of various kinds; the materials concerned in these changes remain dormant or inactive, so long as they are not subjected to its influence; but when it is allowed to operate upon them, it gives occasion to acts of decomposition and new combination, to which acts it may be properly said to be the *stimulus*.

51. Hence the dependence of *Vital* actions upon certain external stimuli, as well as upon the properties of the organism which manifest them, is no greater than the dependence of any of the phenomena, exhibited by an inorganic substance, upon some other agency external to itself. In fact, *no change whatever can be said to be truly spontaneous;* that is, no property can manifest itself, unless it be called into action by some stimulus fitted to excite it. Thus when spontaneous decomposition (as it is commonly termed) occurs in an organized or inorganic substance, it is due to the forces generated by the mutual attraction between certain elements of the substance, and the oxygen of the atmosphere; and this attraction is sufficient to overcome the attraction, which tends to hold together the particles in their original state. If the air be totally excluded, decay will not take place;* because no new force comes into operation, to cause a separation of the components from their original modes of union. The influence of the Vital Stimuli,—that is, the conditions in regard to Heat, Light, &c., which are essential to Vital activity,—will be fully explained in the next Chapter; and at present it will be sufficient to remark, that the degree in which they are supplied possesses a well-marked influence upon the amount of activity and energy manifested in the actions of the organized structure; that there is a limitation in the case of each of them, as to the degree in which it can operate beneficially, the limitation being usually narrower and more precise, according to the elevation of the being in the scale; that an excessive supply

* On this principle, meats, vegetables, and even liquid soups, are now largely preserved, for the use of persons undertaking long voyages; by enclosing them in tin cases, carefully soldered up. There is no limit to the time, during which decomposition may thus be prevented.

may be destructive to the vital properties of the structure, by over-stimulating it and thus causing it to live too fast, or by more directly producing some physical or chemical change in its condition; and that a deficiency will keep down or suspend all vital activity, leaving the structure to the unrestrained operation of those agents which are always tending to its disintegration, and consequently occasioning a speedy loss of the vital properties,—save in those cases in which they may be preserved in a dormant condition, and which are exceptions to the general rule, that the death or departure of the vital properties follows closely upon the cessation of vital actions.

52. Our fundamental idea of *Life*, then, is that of a state of constant change or action; this change being manifested in at least two sets of operations;—the continual withdrawal of certain elements from the inorganic world;—and the incorporation of these with the peculiar structures termed organized, or the production from them of the germs that are hereafter to accomplish this. As the *conditions* of this continual change, we recognize the necessity of an *organized structure* on the one hand, or of a germ which is capable of becoming so; whilst we also perceive the necessity of a supply of certain kinds of matter from the inorganic world, capable of being combined into the materials of that structure, which may be designated as the *alimentary substances;* and, further, we see that the organism can exert no influence upon these, except with the assistance of certain other agencies, such as light, heat, &c., which are termed *vital stimuli.* This expression includes all the essential phenomena of *vegetative* or *organic* life; whether as witnessed in the lowest or highest members of the Vegetable kingdom; or as displayed in a large proportion of the structures composing the Animal fabric.

53. But just as we find among Inorganic bodies, that various kinds are to be distinguished by their different properties, whilst all agree in the general or essential properties of matter, so do we find that living organized substances are distinguished by a variety of properties inherent in themselves, whilst they all agree in the foregoing general or essential characters. In many instances, the difference of their properties is as *obviously* coincident with differences in their structure and composition, as it usually is among the bodies of the Mineral world: thus we always find the property of Contractility on the application of a stimulus, restricted to a certain form of organized tissue, the Muscular; and we find that the property by which that stimulus is capable of being generated and conveyed to a distance, is restricted to another kind of tissue, the Nervous. In a great number of cases, however, very obvious differences in properties manifest themselves, when no perceptible variations exist, either in structure or composition; thus it would be impossible to distinguish the germ-cell of a Zoophyte from that of Man, by any difference in its aspect or composition; yet neither can be developed into any other form than that of the parent species, and they must be regarded, therefore, as essentially different in properties. In the same manner we shall find

that, in the same organized fabric, there are very great varieties in the actions of its component cells, which indicate a similar variety in their properties; and yet they are to all appearance identical. But there can be no reasonable doubt, that differences really exist in such cases; though our means of observation are not such as to enable us to take cognizance of these, by the direct impressions they make upon our senses. Analogous instances are not wanting in the Mineral world; for the Chemist is familiar with a class of compounds designated *isomorphous*, in which, with perfect similarity in external form and physical properties, there is a difference, more or less complete, in chemical composition.

54. Whatever may be the *peculiar* vital properties possessed by an organized tissue, we find that they are always dependent upon the maintenance of its characteristic structure and composition, by the nutritive operations of which we have spoken; and that they thus form a part, as it were, of the more general phenomena of its Life. They manifest themselves with the first complete development of the tissue; they are retained and exhibited so long as active nutritive changes are taking place in it; their manifestation is weakened or suspended if the nutritive operations be feebly exerted; and they depart altogether, whenever, by the cessation of those actions, and the uncompensated influence of ordinary Chemical forces, the structure begins to lose that normal composition and arrangement of parts, which constitutes its state of *organization*. Hence we may regard these peculiar properties as conformable, in all the essential conditions of their existence, with those more general properties, which have been previously dwelt upon as characterizing a living organized structure.

3. *Connection between Vitality and Organization.*

55. The idea that new properties may be called forth or developed by a new combination of elements, and by a new arrangement of particles,—and that, consequently, the class of properties included under the general term *vital* is dependent upon the peculiar state of matter which is designated as *organized*,—is so perfectly conformable to what is seen elsewhere, and is so fully sufficient to explain all observed phenomena, that it would scarcely seem necessary to use any further argument in support of it. But the notion has been entertained, that Vitality is *a something superadded* to matter, and that it is absurd to suppose that the phenomena of Life can be produced by *any* combinations of matter; and this indeed so generally prevails, that it seems desirable to carry our investigations with regard to the causes of Vital phenomena a little further.

56. We have seen that the properties of any kind of matter, even those with which we are most familiar, require certain conditions for their manifestation. Even the properties of which we take most direct cognizance by our senses, do not manifest themselves to us,

until they have made a change in the condition of our own organs. And in regard to those, which require a stimulus of some kind to call them into action, our acquaintance with them entirely depends upon whether the conditions of their action have been afforded. Thus, to go back to a former illustration, supposing a new chemical element to be discovered, we could not know its properties in regard to heat, electricity, or magnetism, the mode of its combination with other elements, the nature and properties of the compounds produced, their reactions with other compounds, &c. &c., until we have tried a complete series of experiments upon it,—that is, until we have placed it in all the circumstances or conditions requisite to manifest the properties, with which we seek to become acquainted, or whose absence we seek to determine if they do not exist. Now we might have made all the experiments we could devise upon such a body; and yet we might have failed in detecting some remarkable and distinguishing property inherent in it, simply because we had not placed it in the requisite circumstances for the manifestation of this peculiarity. Further, even in the elements or compounds with which we are best acquainted, it is very possible that properties exist, of which we as yet know nothing, simply because they have not yet been called into action by the requisite combination of conditions. For example, no one would have thought it possible, a few years since, that water could be *frozen* in a *red-hot* metallic vessel; and yet this is now known to be effected with ease and certainty, in the proper combination of conditions.

57. Again, it is by no means a sufficient definition of one of these elements,—Oxygen, for example,—to enumerate its properties in its simple or uncombined state; these are the properties of oxygen *gas;* but a complete enumeration of the properties of oxygen itself would include a reference to those of every compound substance into which it enters, as well as to the conditions under which they manifest themselves. We are accustomed to think of the properties of these compounds, as if they were something altogether distinct from those of the elements of which they are composed; thus in considering the properties of *water*, we commonly lose sight of the fact, that it is formed by the union of oxygen and hydrogen, and that we must regard these elements as possessing, in a dormant state, the capability of manifesting such properties, when they are brought together under certain conditions. Yet we cannot reason upon the ordinary operations of Chemistry, without coming to the conclusion, that the very act of combination calls forth or develops properties, which were pre-existent in the components, and which became manifest as soon as these were placed in the circumstances required to display them.

58. It must not be forgotten, that the properties of a compound substance are, in general at least, altogether different from those which present themselves in either of its components; so that we could not in the least degree judge of the former from the latter, or of the latter from the former. What more different, for example, from the physical and chemical properties of Water, from those of either the Oxygen

4

or the Hydrogen that enter into its composition? Or what more different than the properties of a neutral salt, from those of the acid and alkali by whose union it is produced? We are continually witnessing, then, the complete change effected in the *sensible* properties of bodies, by acts of combination or separation; these acts calling forth or developing properties that were previously dormant, and reducing to the dormant condition those which were previously sensible. That this is the true way of accounting for the phenomena would appear from the fact, that in all cases the *converse* change brings back the original properties; thus the oxygen and hydrogen resulting from the decomposition of water, have all the properties of oxygen and hydrogen that are being combined into water. Their properties, then, have undergone *no real* change; the *ostensible* change being due to the development of some of the properties of the elements, and the reduction of others to the dormant state, by the very alteration of their conditions.—Even a change in the condition of a single body, without any combination, may cause new properties to be manifested by it, and old ones to become dormant. Thus the particles of water have so strong an attraction for each other, at a low temperature, as to become aggregated in a crystaline form, and to produce a dense solid mass; at somewhat a higher temperature, their mutual attraction is so slight, that a very small amount of mechanical force is sufficient to separate them, and they move upon each other with the utmost freedom; whilst at a still higher temperature, they manifest a power of mutual repulsion, which increases with the greatest rapidity with every augmentation of temperature. Yet when the temperature of the substance is lowered to its former standards, we observe that it first returns to the liquid, and then to the solid form; and that, in those states, it manifests all the properties which before characterized it.

59. Again, not merely the physical, but the chemical properties of bodies may be affected by a change in their mechanical condition. Thus, it is well known that oxygen and iron, at ordinary temperatures, have a mutual affinity, which is only sufficient to produce a slow combination between them; whilst at high temperatures, that affinity is such as to cause their rapid and energetic union. Now if iron, in a state of very minute division,—such as it possesses when set free from the state of oxide by means of hydrogen, at the lowest possible temperature,—be brought into contact with oxygen or even with atmospheric air, at ordinary temperatures, it immediately becomes red-hot, and is converted into an oxide. The minuteness of the division, predisposing to chemical union, appears to be the occasion of our power of causing many substances to combine, when one or both are in the *nascent* state (that is, when just set free from some other combination), which could not be made to unite in any more direct manner; thus, when a quantity of any preparation of Arsenic, however minute, is dissolved in fluid in which hydrogen is being generated, the hydrogen will detach the metal from its previous com-

bination, and will pass forth in union with it, as arseniuretted hydrogen,—a compound which cannot be formed by the direct union of the elements. In like manner, in that mechanical mixture of three finely-divided substances, which we call Gunpowder, the rapidity with which combustion is propagated through the largest collection of it, is entirely dependent upon the minute subdivision of its components, and the very close approximation of their particles. Hence it may be very correctly said, that the true chemical properties of the substances are not manifested, except when they are in a state of very minute division; and that these are in fact obscured, by the aggregation of the particles into masses.

60. Thus, then, we are at no loss to discover examples, in the Inorganic world, of an interchange of the sensible properties, both Chemical and Physical, of the bodies composing it, by a change in the conditions in which they are placed. And it may be stated as a general fact, that we never witness the manifestation of new properties in a substance, unless it has undergone some change in its own condition, of which altered state these properties are the necessary attendants. We have no right, therefore, to speak of any *property* as *distinct* from the matter which exhibits it; or as capable of being *superadded* to it, or *subtracted* from it. On the other hand we are led to the conception of *properties* as either *dormant* or *latent*, on the one hand; or as *active* or *sensible* on the other; the difference being entirely due to the condition of the substance. Thus, oxygen and hydrogen have a latent or dormant affinity for each other; this does not manifest itself in either of them, so long as they are separate; nor does it manifest itself at ordinary temperatures, when they are mingled together. But if through such a mixture we transmit an electric spark, or if we raise the temperature of the smallest part of it by the contact of a heated body, or if we simply introduce into it a portion of platinum in a state of minute division, the requisite stimulus or excitation is given to these affinities, and chemical union of the two substances is the result.

61. Now if we apply these views to the phenomena of Life and Organization, we see that they enable us to regard these phenomena as *analogous* in character to those of the Inorganic world, though not *identical* with them; and they lead to a simplification of our ideas of them, which more clearly marks out the path to be pursued in their investigation. We find that the essential materials of Animal and Vegetable structures are the four elements, Oxygen, Hydrogen, Carbon, and Nitrogen; these are distinguished by the extraordinary number and variety of the combinations into which they will enter,—so much so, indeed, as to constitute, in this respect, a group quite distinct from all the other elementary substances. Now we are perfectly justified by what we elsewhere see, in attributing to these elements the property or dormant capability of exhibiting *vital* actions (in addition to the ordinary chemical ones with which we are familiar), so soon as they are placed in the requisite conditions; in other

words, as soon as they are made a part of the living system by the process of Organization. It is only the peculiarity of the conditions required to manifest this capability, which prevents us from recognizing it as an ordinary property of matter, or at least of those forms of it, which we know by experience to be capable of entering into organized structures.

62. Thus we perceive, that Vital properties are called forth or developed in the substance of the germ, whilst this substance is being organized by the agency of its parent; these vital properties are such as to give it the means of assimilating and organizing the materials supplied by the inorganic world, and whilst thus making them a part of its own structure, to cause them to manifest *their* vital properties; and these are exercised in their turn, in making further additions to the growing structure, and in the formation of the reproductive germ. In this germ we cannot perceive a single trace of the future being; the various organs and structures of which are evolved by a process of subsequent development. And it is probable that, in the complete organism, not a single particle remains of those which originally constituted its germ. Now it seems absurd to suppose that in a single cell-germ, a molecule almost invisible with a high magnifying power, a force is concentrated, which is afterwards to be diffused through the whole structure of a vast tree; or through the ever-changing fabric of a complex animal; and which is not only to animate the individual organism, but is to occasion the production of thousands or tens of thousands of germs, each possessing a similar force, and capable of imparting it to *their* successors. On the other hand, if we suppose that the germ calls forth, or excites, the dormant properties of the combining elements (like the spongy platinum, or the electric spark, in a mixture of oxygen and hydrogen),—that it thus originates, first a chemical combination, and then a peculiar structural arrangement, —that in consequence of this new combination and arrangement, the elements then manifest peculiar properties in place of their old ones, which last as long as they exist in that condition,—that, when their union in the organized fabric is dissolved, they lose these newly-manifested properties, return to their original form, and manifest precisely the same properties as before they were combined,—and that they are capable of being thus operated on, time after time, their properties not being added to, or lost, but those which were latent being developed, and those which were at first sensible becoming latent,—we get rid of every difficulty, at the same time that we reason in accordance with the fundamental principles of Logic and Philosophy, which forbid us to assume any agency that is not requisite to explain the phenomena.

63. The elements, Oxygen, Hydrogen, Carbon and Nitrogen, in a certain state of combination and arrangement, form the substance which we term Muscular fibre; and they then manifest certain peculiar properties, which we designate as *vital*. On the other hand, those same elements exist in nearly the same proportions, but in a

different state of combination and arrangement, in the substance which we term Cyanate of Ammonia; and they then exhibit a different set of properties, which we call Physical and Chemical. Now we have just as much right to say, that the contractility of muscular fibre results from the peculiar combination and arrangement of the elementary particles in its substance, as we have to say that the solidity, translucency, hardness, and other qualities of the salt (all of which are opposed to the vital properties, and cannot co-exist with them), are necessarily connected with *its* peculiar mode of combination and crystaline aggregation. If we were acquainted with these elements *only* as they exist in organic compounds, their transposition into a crystaline salt would be almost as marvelous to us, as the opposite change is now.

64. The general history of the Phenomena of Life is fully conformable with the view, that the Vital properties of a tissue are dependent upon that state of combination and arrangement which is termed Organization. As long as each tissue retains its normal or regular constitution, renovated by the actions of absorption and deposition through which that constitution is preserved, and surrounded by those other conditions which a living system alone can afford, so long, we have reason to believe, it will retain its vital properties,—and no longer. And just as we have no evidence of the existence of vital properties in any other form of matter than that which we call organized, so have we no reason to believe that organized matter can retain its regular constitution, and be subjected to its appropriate stimuli, without exhibiting vital actions. The advance of pathological science renders it every day more probable (indeed the probability may now be said to amount to almost positive certainty), that derangement in *function*,—in other words, an imperfect or irregular *action*,—always results, either from some change of structure or composition in the tissue itself, or from some corresponding change in the stimuli by which the properties of the organ are called into action. Thus, when a Muscle has been long disused, it can scarcely be excited to contraction by the usual stimulus, or may even be altogether powerless; and minute examination of its structure shows it to have undergone a change, which is obvious to the microscope, though it may not be perceptible to the unaided eye, and which results from imperfect nutrition. Or, again, convulsive or irregular actions of the Nervous system may be produced, not by any change in its own composition, but by the presence of various stimulating substances in the blood, although their amount be so small that they can scarcely be recognized.

65. As there is a constant tendency, in the Animal tissues more especially, to spontaneous decay, so must the maintenance of the vital properties depend upon their continual regeneration by the nutritive operations. Hence we have no difficulty in accounting for the Death of the whole system, on the cessation or serious disturbance of any one important function; for any such check or change must suspend or

disorder the nutrient processes, in such a degree that they can no longer maintain the normal constitution of the several tissues. But as there is a great variety in the rapidity of the decomposition of the tissues, when the act of nutrition is suspended, so do we witness a corresponding variety in the duration of their vital properties, after that permanent severance of the chain of functions, which is distinguished as *somatic* death,—i. e., the death of the *body* as a whole. It is by the Circulation of the Blood, that the connection of the different functions is essentially maintained; that fluid being not only the material for the nutrition of the tissues, but in many cases serving also as the stimulus to their activity. Hence with the permanent cessation of the Circulation, *somatic* death must be regarded as taking place.

66. Yet after this, we observe that vitality lingers in the tissues; and that it departs from them only as they lose their proper composition. Thus we find that, although the Nervous *centres* cannot *originate* the stimulus necessary to produce Muscular contraction, after the Circulation has ceased,—yet the Nervous *fibres* can *convey* such a stimulus, long after somatic death; so that contractions may be excited in muscles by the application of galvanism, or of mechanical or chemical stimulants, to the trunks that supply them. The *molecular* death of the Nervous tissue, therefore, has not yet taken place. After a time, however, this power is lost; the tissue no longer exhibits its distinguishing vital properties; and incipient decomposition and change of structure manifest themselves. Yet for some time after this, the Muscular tissue, especially in a cold-blooded animal, continues to possess its peculiar contractility; for contractions may be excited in it, by stimuli directly applied to itself, long after the nerves have ceased to convey their influence. Sometimes, indeed, the contractility of muscle endures, until changes in its structure and composition become evident to the senses; thus the heart of a Sturgeon, removed from the body, and hung up to dry, has been known to continue alternately contracting and dilating, until the movement produced a crackling noise, in consequence of the dryness of the texture. Again, there is evidence, that various processes of nutrition and secretion may go on, for some time after somatic death, and even after the removal of the organs from the body, provided a sufficient quantity of blood remains in them; and the blood itself retains its vitality, so as not to coagulate, whilst contained in the vessels of tissues still living.

67. Hence it is, that parts which have been *completely* separated from the body may often be reunited with it, if they were previously in a healthy state, and too much time has not elapsed; thus, there are many cases on record, in which fingers, toes, noses, or ears, that have been accidentally chopped off, have been made to adhere and grow as before, by bringing the cut surfaces into contact, even some hours after their severance. It is evident, then, that the parts so severed cannot have lost their vitality; since no treatment could produce union between a dead mass and a living body. And we are

fully justified in assuming that, in cases where attempts at such reunion have not been successful, the death of the separated part has resulted from the too-prolonged interruption of its regular nutritive operations, whereby chemical and physical changes have taken place in it, and destroyed the peculiar structure and composition of its several parts. The ordinary phenomena of Death, therefore, as well as those of Life, bear out the views which have been here advanced.

68. But it has been maintained by those who consider Vitality as something superadded to an Organized Structure, essentially independent of it, and capable of being subtracted from it, that Death frequently takes place under circumstances, which leave the organism as it was; so that "the dead body may have all the organization it ever had whilst alive." For such an assumption, there is not the least foundation. In nearly all cases in which death takes place as a result of disease, the connection between changes of structure and composition, either in the tissues or in the blood, and such a loss of the vital properties of some part or organ as is sufficient to bring the Circulation to a stand, is so palpable as to require no proof; and in by far the greater majority of cases in which it is not at once obvious, a more careful scrutiny will reveal it. It must be confessed on both sides, that our means of investigation, and our knowledge of the normal structure and composition of the tissues and the blood, are not yet sufficient to enable us to detect minute shades of alteration, nor to assert what extent of change is inconsistent with the continuance of life. And as no one has yet shown, by the careful and exact microscopical and chemical examination of the solids and fluids of a dead body, that it has all the organization it had whilst alive, the assertion above quoted is totally unwarranted by experience, and is contradicted by all our positive knowledge of the matter. (See § 187.)

69. But it has been urged, that Death may result from the sudden operation of some agency of an *immaterial* character, which leaves no trace behind it,—such as a powerful electric shock, or a violent mental emotion. Here, too, the argument entirely fails. It is *impossible* that a powerful electric shock could be transmitted through a mass like the animal body, composed of elements in such a loose state of combination that they are always undergoing decomposition, without producing important *chemical* changes in it; and its imperfect conducting power renders it equally liable to *physical* disturbances. As a matter of fact it has been noticed, that the bodies of animals killed by electricity pass into decomposition with unusual rapidity; showing that the ordinary chemical affinities of their components have received a powerful stimulus; and it has also been ascertained, that when Eggs in process of development have had their vitality destroyed by an Electric shock, the minute vessels of the *vascular area* (Chap. XI.) have been ruptured.—Nor is it more difficult to explain the immediate cause of death, as a result of Mental emotion. In some cases, an obvious physical change has been

produced by the too violent action of the heart, the movements of which are stimulated by the emotion ; thus, even in a healthy person, rupture of the heart or aorta has been known to take place, an occurrence to which those affected by previous disease of that organ are much more liable. Where there is *any* disorder in the heart's action, resulting from thickened valves, narrowed orifices, &c., the physical influence of mental emotion can be easily accounted for. But it must be admitted that cases have occurred, in which no such explanation can be offered; sudden death having taken place without any perceptible structural cause. We are not obliged, however, to have recourse to any hypothesis for an explanation of even these cases, which is not borne out by ample analogy. For it is well known that mental emotions exert a powerful influence over the composition of the *fluids* of the body, and are capable of *instantaneously* altering these. Thus in many human beings, and still more in the lower animals, alarm or agitation will occasion the immediate disengagement of powerfully odorous secretions, which must have resulted from new combinations suddenly formed. And there can be no doubt that a fit of passion may immediately occasion such a change in the milk of a nurse, as renders it a rank poison to the infant. There is no reason to doubt, therefore, that the blood itself may undergo changes of analogous character from the same cause ; and that it may become a violent poison to the individual himself, instead of being the source of wholesome nutriment, or the stimulus to vital activity.

70. To conclude, then ;—we only know of *Vital action*, as exhibited by an Organized structure, under the influence of certain stimuli; and we only know of *Vitality*, or the state or endowment of the being that exhibits that action, as conjoined with that particular aggregation and composition which we term Organization. The real cause of that endowment must be traced to the properties of the original elements of the structure exhibiting it, and to the conditions under which they came into action. We have thus two objects for consideration, in regard to the process of organization and the development of the vital properties ; namely, the original component elements, and the organizing germ which is the means of bringing them into combination. The former are *permanent* in their character, for whatever be the nature of the changes they are made to undergo, in the various acts of combination, they manifest their original properties when restored to their pristine state, and can thus be successfully made to form part of innumerable compounds, organic or inorganic. On the other hand, the properties of the germ are but transitory ; its own existence, as well as the duration of the entire organism to which it gives rise, is limited ; and the whole Organized Creation would speedily come to an end, and would be resolved into its pristine elements, if a provision had not been made in the reproductive process, for antagonizing the continual decay of living beings by a continual succession.

71. For the existence of those dormant properties in the elements commonly termed inorganic, which enable them to become component parts of organized structures and then to perform vital actions, we can assign no other cause than the Will of the Creator. The constancy of the actions which result from them, when the conditions are the same,—that is, their conformity to a fixed plan, or (in the language commonly employed) their subordination to *laws*,—indicates the constancy and unchangeableness of the Divine Will, as well as the Infinity of that Wisdom, by which the plan was at first arranged with such perfection, as to require no departure from it, in order to produce the most complete harmony in its results.

72. So also, if we endeavour to assign a cause for the existence of a cell-germ, we are led at first to fix upon the vital operations of the parental organism by which it was produced; and for these we can assign no other cause than the peculiar endowments of *its* components, brought into activity by the cell-germ that originated it. Thus we are obliged to go backwards in idea from one generation to another; and when at last brought to a stand by the origin of the race, we are obliged to rest in the Divine Will as the source of those wonderful properties, by which the first germ developed the first organism of the race from materials previously unorganized, this organism producing a second germ, the second germ a second organism, and so on without limit, by the uniform repetition of the same processes. Yet we are not to suppose that the *continuation* of the race is really in any way less dependent upon the Will of the Creator, than the *origin* of it. For whilst Science leads us to discard the idea that the Deity is continually *interfering*, to change the working of the system He has made,—since it everywhere presents us with the idea of uniformity in the plan, and of constancy in the execution of it,—it equally discourages the notion entertained by some, that the creation of matter, endowed with certain properties, and therefore subject to certain actions, was the *final* act of the Deity, as far as the present system of things is concerned, instead of being the *mere commencement* of His operations. If it be admitted, that matter owes its origin and properties to the Deity, or, in other words, that its *first existence* was but an expression of the Divine Will, what is its *continued existence*, but a continued operation of that same Will? To suppose that it could continue to exist, and to perform its various actions, *by itself*, is at once to assume the property of *self-existence* as belonging to matter, and thus to do away with the necessity of a Creator altogether;—a conclusion to which it may be safely affirmed that no ordinarily-constituted Man can arrive, who reasons upon the indications of Mind in the phenomena of Nature, in the same way as he does in regard to the creations of Human Art.

CHAPTER II.

OF THE VITAL STIMULI.

73. It has been shown in the preceding Chapter, that the *most general* conditions of Vital phenomena are two-fold ;—one set being supplied by the organized structure, which is endowed (in virtue of its organization) with certain peculiar properties, but which is inert so long as it is altogether secluded from the influence of external agents; —and the other being furnished by external agents of various descriptions, some of which supply the materials from which the organized structure is built up, whilst others serve to stimulate or excite the process of organization, or call forth the peculiar properties of the organized structure. Thus in the case of the germinating seed, the embryo within, possessed of a peculiar organization, and capable of development into a living fabric of complex structure, remains in a dormant state, until it is aroused to activity by the influence of warmth, air, and moisture. Here, then, we have the distinction between the *organism* and the *external agents* most palpably exhibited. No vital activity can manifest itself without the concurrence of *both;* and the germ could no more produce a plant without the materials supplied to it by the external world, and the stimuli which excite it to the action of appropriating these, than the latter could develop themselves into a plant, without the formative agency of the germ.

74. In this dependence of *Vital* action upon the concurrence of several conditions, we only see that which is true, under a simpler form, of *Chemical* action; and here, too, we trace the distinct agency of the *materials* employed, and the *stimuli* which excite their mutual affinities, and thus bring about their union. The *materials* of Chemical Action are the substances (either elementary or composite), which are ready to enter into new combinations with each other; and that readiness or Affinity is one of their distinguishing properties. Thus the mutual affinities of oxygen and hydrogen, or of an acid and an alkali, are characteristic properties of these substances respectively. Sometimes this affinity is strong enough to cause union between the substances under any ordinary circumstances. But in many other cases, a stimulus of some kind is necessary to bring these affinities to bear (so to speak) upon one another. Now the *stimuli* to Chemical action belong to the class of agents commonly termed *imponderable*,— namely, Light, Heat, and Electricity; and the union between two substances, which were previously altogether dormant in regard to each other, although in close contact, may be frequently caused to take place, with various manifestations of energy, by the momentary influence of one of these agents. Thus, when chlorine and hydrogen are

mingled together in a bottle, and this is placed in darkness, they may be kept for any length of time without change; but if they are exposed to diffused daylight, they slowly unite; and if they be subjected to the direct rays of the sun, instantaneous explosion takes place, with production of hydrochloric acid. Here, then, the agency of *Light* brings the previously-dormant affinities of these two bodies into a state of activity in regard to each other. The same effect may be produced by *Heat;* for a union of the two gases, with a violent explosion, takes place when any incandescent substance is introduced into the mixture. And a like result is produced by *Electricity;* hydrochloric acid being generated under the same circumstances, by the influence of the electric spark.*

75. In like manner it is requisite to distinguish, among the *external agents* that concur with the organic germ to produce an organized structure, between those which furnish the *materials* of that structure, or which enter into chemical union with its elements, and those which act as *stimuli* to its actions; and we find that this distinction coincides, as in the former case, with the division between the *ponderable* or material, and the *imponderable* agents. Under the former group are included the various elements, which are capable of being appropriated by the organism as the materials of its own structure, and which are possessed of peculiar properties that are then developed; in other words, the various articles of food. The oxygen of the atmosphere, whose union with certain elements of the organism, in the process of Respiration, is also an agent essential to its functional activity,—belongs to the same division. The general dependence of the living organized body upon food and oxygen, has been, however, already noticed; and it will be preferable to defer the detailed consideration of the mode and conditions under which they act upon it, until the history of the Nutritive operations is more fully entered upon. This will be the fitting opportunity, however, for the examination of the general influence of the Imponderable agents, and of some others which cannot be so well treated of elsewhere.

76. In regard to all these Vital Stimuli it may be observed, that the dependence of Vital Action upon their *constant* influence is greater in proportion to the high organization of their structure, and *vice versa;* so that beings of simple organization are capable of enduring a deprivation of these stimuli, which would be fatal to those higher in the scale. This will be partly understood, when it is borne in mind that the higher the development of the living being, the more complete is the distribution of its different actions amongst separate organs,—the more close, therefore, is their mutual dependence,—and the more readily, in consequence, are they all brought to a close by the inter-

* Although the conditions of this union appear limited to the mutual proximity of the two bodies, and to the influence of *one* of these three stimuli, yet it may be asserted that they are probably more complex than they appear; for although a high temperature is competent to produce their union when Heat is employed alone, yet it is probable that neither Light nor Electricity would suffice to effect it, if they were not kept in the gaseous state by the large amount of *latent heat* they possess.

ruption of any one. But there is no doubt, that the actions of even the individual parts of the higher organisms require for their excitement a greater supply of these stimuli, than the similar actions of the corresponding parts in the lower: whilst if these stimuli be exerted upon the lower with the intensity that is required for the higher, they destroy the vital properties of the tissues altogether, by the excess of their action. This distinction is most obvious in regard to the relative influence of Heat, upon warm-blooded and cold-blooded animals; of which examples will be given hereafter.

77. It may also be observed of the influence of these, as of that of other stimuli whose agency is less general, that it is rather *relative* than *absolute;* being frequently dependent upon the degree of *change*, rather than upon the actual measure of the *amount* of the stimulus. This constitutes a marked difference between the influence of these stimuli on mere chemical compounds, and their operation on bodies endowed with vitality. In the former case, their action is always uniform; thus the same amount of heat, the same exposure to light, the same charge of electricity, would be required to produce a given Chemical effect, how often soever the action might be repeated. But this is not the case with living bodies; since an increase or diminution in the intensity of the vital stimuli, which, if made *suddenly*, would be scarcely compatible with the continuance of Life, may be so brought about, as to produce no marked change in its phenomena,—the organism possessing a certain power of adapting itself to conditions which are habitual to it, and thus allowing great changes in these conditions to be *gradually* effected, without any serious disturbance.—Thus of two individuals of the same species, one may become torpid at a temperature of 60°, because it has been accustomed to a temperature of 70°; whilst another, habituated to a temperature of 60°, would require to be cooled down to 50°, in order to induce torpidity; —the influence of temperature upon the vital conditions being proportioned, more to the variation from the usual standard, than to the actual elevation of that standard. Yet the first of these individuals might be gradually habituated to live in the same temperature with the second; and to require the same amount of further depression to induce torpidity. (See § 129.)

78. It is a very curious fact that, whilst the lower classes of living beings are more capable than the higher of bearing the deprivation of these Vital stimula, they are at the same time more liable to alterations in their own structure and development, in consequence of variations in the degree of their agency, or from other causes external to themselves. Thus the *forms* of the lower tribes of Plants and Animals are liable to be greatly affected by the conditions under which they grow; and these especially modify their degree of development. It seems as if the formative power were less vigorous in the lower, than in the higher classes; so that the mode in which it manifests itself in the former is more dependent upon external influences; whilst in the latter it either predominates over them, causing the regular actions

to be performed, or gives way altogether.—The same principle applies to the early condition of the higher organisms; their embryos, like those beings of permanently low type which they resemble in degree of development, being liable to be affected by modifying causes, which the perfect beings of the same kind are able to resist. It is in this way that we are to explain the influence, which the female parent exerts upon the embryo; the germ of which she receives from the male, but to which she supplies the materials for its development.

1. *Of Light, as a Condition of Vital Action.*

79. The importance of this agent, not only to the Vegetable, but to the Animal World, is not in general sufficiently estimated. Under its influence alone, can the first process be accomplished, by which inorganic matter is transformed into an organic compound, adapted by its nature and properties to form part of the organized fabric. The following is an example of the simplest phenomenon of this kind; and it demonstrates the influence of Light the more clearly on account of that simplicity. "If we expose some spring-water to the sunshine, though it may have been clear and transparent at first, it presently begins to assume a greenish tint; and, after a while, flocks of green matter collect on the sides of the vessel, in which it is contained. On these flocks, whenever the sun is shining, bubbles of gas may be seen, which, if collected, prove to be a mixture of oxygen and nitrogen, the proportion of the two being variable. Meanwhile the green matter rapidly grows; its new parts as they are developed, being all day long covered with air-bells which disappear as soon as the sun has set. If these observations be made upon a stream of water, the current of which runs slowly, it will be discovered that the green matter serves as food for thousands of aquatic Insects, which make their habitations in it. These insects are endowed with powers of rapid locomotion, and possess a highly organized structure; in their turn they fall a prey to the Fishes which frequent such streams."* Such is the general succession of nutritive actions in the Organized Creation. The highest Animal is either directly dependent upon the Vegetable Kingdom for the materials of its fabric, or it is furnished with these by some other Animal, this again (it may be) by another, and so on; the last in the series being *always* necessitated to find its support in the Vegetable kingdom, since the Animal does not possess the power of causing the Inorganic elements to unite into even the simplest Organic compound. This power is possessed, in a high degree by Plants; but it can only be exercised under the influence of *Light.* We shall now examine, more in detail, the conditions of this influence, both in the instance just quoted, and in others drawn from the actions of the higher Vegetable organisms.

80. The "green matter of Priestley," (as it is commonly called,)

* Prof. Draper, on the Forces which produce the Organization of Plants, p. 15.

which makes its appearance when water of average purity is submitted to the action of the Sun's light, and which also presents itself on the surface of walls and rocks, that are constantly kept damp, is now known by Botanists to consist of *cells* in various stages of development,—the early forms, it may be, of several different species of Confervæ. That these cells all originate from germs, and not from any direct combination of the inorganic elements, appears not only from general considerations, but also from the fact that, if measures be taken to free the water entirely from any possible infusion of organic matter, and to admit into contact with it such air alone as has undergone a similar purification, no green flocks make their appearance, under the prolonged influence of the strongest sunlight. We find, then, that the presence of a germ is one of the conditions indispensable to the chemical transformation in question. It may be asked how it can be certainly ascertained that *light* and not *heat* is the essential condition of this process; seeing that the two agents are combined in the solar beam. To this it may be replied, that a certain moderate amount of heat is undoubtedly necessary; but that no degree of heat without light will be effectual in producing the change, as is easily proved by exposing the water to warmth in a dark place. Moreover, when a certain measure of light is afforded, variations in the amount of heat make very little difference; but we shall presently see that under the same degree of heat, the amount of the change is directly proportional to the intensity of the light. Although, therefore, heat furnishes an essential condition, it cannot be questioned that *light* is the chief stimulus to that process, by which the germ brings into union the elements to be employed in the development of its own fabric.

81. The next question is,—What are these elements, and whence are they obtained? All water that is long exposed to the atmosphere, absorbs from it a certain amount of its constituent gases; but these do not enter it in the proportions in which they are contained in the atmosphere itself; their relative quantities, in a given measure of water, being proportioned to the facility with which they are respectively absorbed by the liquid. Thus carbonic acid is most readily absorbable; oxygen next, and nitrogen least so. From the experiments of Prof. Draper it would appear, that notwithstanding the very small proportion of carbonic acid contained in the atmosphere (usually not more than 1-2000th part), it forms as much as 29 per cent. of the whole amount of air expelled from water by boiling. Of the residue, one-third consists of oxygen, and the remaining two-thirds of nitrogen; so that the proportion of the oxygen to the nitrogen is as *one* to *two*, instead of being *one* to *four*, as in atmospheric air. The absolute quantity of this water-gas, contained in any measure of water, is subject to variation with the temperature; the quantity being diminished as the temperature rises.—Now when water thus impregnated with carbonic acid, oxygen, and nitrogen, and containing the germs of aquatic plants, is exposed to the sun's light, a

development of vegetable structure takes place, indicated by the green flocculent appearance, as already mentioned. If the changes, which are now occurring in the water, be examined, we find that the carbonic acid is diminishing in amount; and that oxygen is being evolved. The growing mass increases in volume and weight; and after a time exhausts the whole carbonic acid originally contained in the water. If then it be prevented from receiving an additional supply, the process stops; but as conducted naturally, there is a free exposure to the atmosphere, through which carbonic acid is diffused; and hence, as fast as it is removed by decomposition, it is restored by absorption.

82. Here then are the conditions and materials; what is the result? As a consequent of the conjoint action of light and of a vegetable cell-germ, with a moderate degree of heat, upon carbonic acid and water, we find a vegetable structure produced, whose fabric consists of carbon, united with the elements of water. Whether this union is really as simple and direct, as is implied by this expression, or whether the same proportions of oxygen, hydrogen, and carbon are united in a different form, is not a matter of consequence to the present inquiry; the general fact being, that by the decomposition of the carbonic acid, oxygen is set free, and carbon is made to unite with the elements of water; so as to form an organic compound, which is appropriated by the Vegetable organism as the material for its growth.—How far Light is also concerned in the production of the protein-compounds (of which azote forms a part), that are prepared by Plants for the use of Animals, has not been yet ascertained; but it is probable that these are not the less dependent upon its agency for their formation, since they are generated under the same circumstances with the preceding. Indeed it may be questioned whether a minute quantity of azote is not an essential part of the *contents* of every vegetable cell, though it does not enter into the composition of the cell-wall.

83. The process whose conditions we have thus examined, is carried on in the individual cells, that compose the highest and most complex Plants, precisely as in those which constitute the entire forms of the lowest. Thus if a few garden-seeds of any kind be sown in a flower-pot, and be caused to germinate in a dark room, it will soon be perceived that although they can grow for a time without the influence of light, that time is limited; the *weight* of their solid contents diminishes, although their *bulk* may increase by the absorption of water; their young leaves, if any should be put forth, are of a yellow or gray-white colour, and they soon fade away and die. But if these plants are brought out sufficiently soon into the bright sunlight, they speedily begin to turn green, they unfold their leaves, and evolve their different parts in a natural way; and the proportion of their solid contents goes on increasing from day to day. If the fabric be then subjeeted to chemical analysis, it is found to contain oxygen, hydrogen, carbon, and azote; united in various proportions, so as to form compounds that differ in the various species, though some,—

such as gum, starch, and cellulose,—are the same in all. If the plants be made to grow in closed glass vessels, under such circumstances that an examination can be accurately made as to the changes they are impressing on the atmosphere, it is discovered that they are constantly decomposing its carbonic acid,—appropriating its carbon, and setting free its oxygen,—so long as they are exposed to the influence of sunshine or bright daylight. They also appropriate a part of the minute quantity of ammonia which is diffused through the atmosphere; extracting its nitrogen to employ it in the production of their azotized compounds. It is capable of being demonstrated by experiment, that these changes are confined to the *green* surfaces of plants, and therefore to the leaves or leaf-like organs, the young shoots, and the stems of herbaceous plants, or of those in which (as in the Cactus tribe) the leaves are wanting and the enlarged succulent stem supplies their place. When these surfaces cease to become green, the decomposing action also ceases; carbon is no longer fixed, and oxygen set free; but, on the contrary, carbonic acid is exhaled: this is the case when the leaves change colour, previously to their fall, in the autumn. The compounds which are thus generated in the green surfaces, are conveyed to the remote parts of the fabric, by the circulation of the sap, and become the materials of their nutrition; and thus the green cells of the leaves have exactly the same function, in ministering to the growth of the fabric of the largest tree, which the green cells of the humble Conferva perform in regard to themselves alone.

84. It has been already mentioned, that the decay which is always taking place in the softer vegetable structures, gives rise to a continual production of carbonic acid, even in the living plant; this process, which must be regarded as a true Respiration, is effected, as in Animals, by the union of the carbon of the Plant with oxygen derived from the atmosphere; and it is carried on, not by the green parts only, but also, perhaps chiefly, by the darker surfaces. Being antagonized during the day by the converse change just described, it can only be made sensible, by placing the plants for a time in an atmosphere in which no carbonic acid previously existed; and it will then be found that, even in full daylight, a certain amount of that gas is exhaled. The fact, however, becomes much more obvious at night, or in darkness; since the decomposition of the surrounding carbonic acid by the green surfaces is then completely at a stand, and a full effect of the respiratory process is seen. Moreover, when a plant becomes unhealthy, from too long confinement in a limited atmosphere, it begins to exhale more carbonic acid than it decomposes; and the same is the case, as just now stated, in regard to leaves that have nearly reached the term of their lives. It does not admit of question, however, that, under ordinary circumstances, nearly the whole carbon of a slow-growing plant is derived from the carbonic acid of the atmosphere; either directly through the leaves, or indirectly by absorption through the roots; and that there must be

a vast surplus, therefore, of the carbonic acid decomposed, over that which is exhaled, during the whole life of the tree,—that surplus being in fact represented by the total amount of carbon contained in its tissues.

85. It is probable that the minute amount of carbonic acid at present contained in the atmosphere, is as much as could be beneficially supplied to Plants, under the average amount of light to which they are subjected, over the whole globe, and throughout the year. It has been clearly shown, that, under the influence of strong sunlight, an atmosphere containing as much as 7 or 8 per cent. of carbonic acid may be not merely tolerated by Plants, but may be positively beneficial to them, producing a great acceleration in their growth; but as soon as the light is withdrawn, it acts upon them most injuriously, causing them speedily to become unhealthy, and altogether destroying their vitality, if they are long subjected to it. Under more cloudless skies than ours, however, the continual supply of a larger quantity of carbonic acid, than our atmosphere contains, is found to be quite compatible with healthy vegetation; especially in the case of Cryptogamic plants, which (as will be presently shown) require a less amount of this stimulus than those of a higher kind. Thus in the lake Solfatara in Italy, an unusual supply of carbonic acid is afforded by the constant escape of that gas from fissures in the bed of the lake, with a violence that gives to the water an appearance of ebullition; and on its surface there are numerous floating islands, which consist almost entirely of Confervæ and other simple cellular plants, growing most luxuriantly on this rich pabulum. And it has been remarked, that the vegetation around the springs in the valley of Gottingen, which abound in carbonic acid, is very rich and luxuriant; appearing several weeks earlier in the spring, and continuing much later in the autumn, than at other spots in the same district. Many circumstances lead to the belief, that at former epochs in the Earth's history, the atmosphere was much more highly charged with carbonic acid than at present; and that to this circumstance, in conjunction with a more intense and constant influence of light and heat, we are to attribute that extraordinary luxuriance of the vegetation of those periods, of which we have most abundant evidence, in the vast beds of disintegrated vegetable matter—Coal—that are of such value to Man, and in the remains which have been more perfectly preserved to us, and which indicate that not only the general forest-mass, but many of the individual forms attained a degree of development, which cannot now be paralleled even between the Tropics.

86. Various experiments have been recently made, with the view of determining more precisely the conditions under which Light acts, in producing the chemical changes that have been now discussed. These experiments for the most part agree in the very interesting result, that the amount of carbonic acid decomposed by plants subjected to the differently coloured rays of the solar spectrum, but otherwise placed in similar circumstances, varies with the *illuminating* power

of the rays, and not with their *heating* or their *chemical* power. The method adopted by Prof. Draper, which seems altogether the most satisfactory, consisted in exposing leaves of grass, in tubes filled with water which had been saturated with carbonic acid (after the expulsion of the previously dissolved air by boiling), to the influence of the different rays of the solar spectrum, dispersed by a prism; these were kept motionless upon the tubes for a sufficient length of time, to produce an active decomposition of the gas in the tubes which were most favourably influenced by the solar beams; and the relative quantities of the oxygen set free were then measured. It was then evident that the action had been almost entirely confined to two of the tubes, one of them being placed in the red and orange part of the spectrum, and the other in the yellow and green. The quantity of carbonic acid decomposed by the plant in the latter of these, was to that decomposed in the former in the ratio of *nine* to *five;* the quantity found in the tube that had been placed in the green and blue portion of the spectrum, would not amount, in the same proportion, to *one;* and in the other tubes, it was either absolutely nothing, or extremely minute. Hence it is obvious that the yellow ray, verging into orange on one side, and into green on the other, is the situation of the greatest exciting power possessed by light on this most important function of plants; and as this coincides with the seat of the greatest illuminating power of the spectrum, it can scarcely be doubted that *light* is the agent here concerned; more especially as the place of greatest *heat* is in the *red* ray, and that of greatest chemical power is in the *blue*, both of which rays were found to be quite inert in the experiment just quoted. It must not be supposed from this experiment, however, that the yellow ray, and those immediately adjoining it, are the *only* sources of this power in the Solar spectrum; since it proves no more than that, when the leaves were exposed to a highly carbonated atmosphere, they could only decompose it under the influence of these rays. It is certain, from other experiments, that plants will grow, in an ordinary atmosphere, under rays of different colours; and it appears that the amount of carbon they severally fix, bears a constant proportion to the illuminating powers of the respective rays.

87. Although this fixation of carbon by the decomposition of carbonic acid, is the most universally-dependent, of all the processes of the Vegetable economy, upon the influence of Light, yet it is not the only one, especially among the higher Plants, in which that agent becomes an important condition. Of the whole quantity of moisture imbibed by the roots, and contained in the ascending sap, a large proportion is *exhaled* again by the leaves; a small part only being retained (together with the substances previously dissolved in the whole) to form part of the fabric. Now upon the rapidity of this exhalation depends the rapidity of the absorption; for the roots will not continue to take up more than a very limited amount of fluid, when it is not discharged again from the opposite extremity (so to speak) of the stem. The loss of fluid by the leaves appears to be a simple

process of evaporation, depending in great part upon the temperature and dryness of the surrounding air; this evaporation, however, does not take place solely, or even chiefly, from the external surface of the leaves, but from the walls of the passages which are channeled out in their interior. Into this complex labyrinth, the outer air finds its way through orifices in the cuticle, which are termed *stomata;* and through these it comes forth again, charged with a large amount of vapour communicated to it by the extensive moist surface, with which it comes into contact in the interior of the leaf. Now the stomata are bounded by two or more cells, in such a manner that they can be opened or closed by changes in the form of these; and this alteration is regulated by the amount of Light, to which the leaves are subjected. When the stomata are opened under the influence of light, the external air is freely admitted to the extended surface of moist tissue within the leaf, and a rapid loss of fluid is the result; more especially if the temperature be high, and the atmosphere in a dry state. On the other hand, if the stomata be closed, the only loss of fluid that can take place from the internal tissue of the leaves, is through the cuticle; the organization of which seems destined to enable it to resist evaporation, so that the exhalation is almost entirely checked. The influence of light upon this important function is easily shown by experiment. If a plant, which is actively transpiring and absorbing under a strong sunshine, be carried into a dark room, both these operations are almost immediately checked, even though the surrounding temperature be higher than that, to which the plant was previously exposed.

88. The effect of the complete and continued withdrawal of light from a growing plant, is to produce an *etiolation* or blanching of its green surfaces; a loss of weight of the solid parts, owing to the continued disengagement of carbon from its tissues, unbalanced by the fixation of that element from the atmosphere; a dropsical distension of the tissues, in consequence of the continued absorption of water, which is not got rid of by exhalation; a want of power to form its peculiar secretions, or even to generate new tissues, after the materials previously stored up have been exhausted; in fine, a cessation of all the operations most necessary to the preservation of the vitality of the structure, of which cessation its death is the inevitable result. A partial withdrawal of the influence of light, however, is frequently used by the Cultivator, as a means of giving an esculent character to certain Plants, which would be otherwise altogether uneatable; for in this manner their tissues are rendered more succulent and less stringy, whilst their peculiar secretions are formed in diminished amount, and communicate an agreeable flavour instead of an unwholesome rankness of taste.

89. There is one period in the life of the Flowering Plant, however, in which the influence of Light is injurious instead of beneficial; this is during the first part of the process of germination of seeds, which is decidedly retarded by its agency. This forms no exception,

however, to the general rule; since the decomposition of the carbonic acid of the atmosphere, and the fixation of carbon in the tissues, do not constitute a part of it; on the contrary, the chemical changes that take place in that substance of the seed, which has been stored up for the nutrition of the embryo, involve the opposite change,—the extrication of carbon, which is converted into carbonic acid by uniting with the oxygen of the atmosphere. It is obvious, then, why light should not only be useless, but even prejudicial, to this process; since it tends to fix the carbon in the tissues, which ought to be thrown off. As soon, however, as the cotyledons or seed-leaves are unfolded, the influence of light upon them becomes as important, as it is on the ordinary leaves at a subsequent time; their surfaces become green, and the fixation of carbon from the atmosphere commences. Up to that point, the young plant is diminishing day by day (like a plant that is undergoing etiolation), as to the weight of its solid contents; although its bulk is increased by the absorption of water. From the time, however, that its cotyledons begin to act upon the air, through the stimulus of light, the quantity of solid matter begins to increase; and its augmentation subsequently takes place, at a rate proportional to the amount of green surface exposed, and the degree of light to which it is subjected.

90. The influence of Light upon the direction of the growing parts of Plants, upon the opening and closing of flowers, &c., is probably due to its share in the operations already detailed. Thus the green parts of Plants, or those which effect the decomposition of carbonic acid (such as the leaves and stems), have a tendency to grow towards the light; whilst the roots, through whose dark surfaces carbonic acid is thrown out by respiration, have an equal tendency to avoid it. That the first direction of the stems and roots of plants is very much influenced in this manner, appears from the fact, that, by reflecting light upon germinating seeds, in such a manner as that it shall only fall upon them from below, the stems are caused to direct themselves downwards, whilst the roots grow upwards. There can be no doubt, however, that Light has also a more direct influence on the development of particular organs in certain Vegetables. Thus when the *gemmules** of the *Marchantia polymorpha* (one of the *Hepaticæ* or Liverworts) are in process of development, it has been shown by repeated experiments, that stomata are formed on the side exposed to the light, and that roots grow from the lower surface; and that it is a matter of indifference *which* side of the little disk is at first turned upwards, since each has the power of developing stomata, or roots, according to the influence it receives. After the tendency to the formation of these organs has once been given, however, by the sufficiently prolonged influence of light upon one side, and of darkness

* These gemmules are analogous to the *buds* of higher plants; and they consist of little collections of cells, arranged in the form of flat disks; which are at first attached by footstalks to the parent plant, but afterwards fall off, and are developed into new individuals.

and moisture upon the other, any attempt to alter it is found to be vain; for if the surfaces be then inverted, they are soon restored to their original aspect by the twisting growth of the plant.

91. The same amount of this stimulus is not requisite or desirable for all Plants; and we find in the different *habitats* which are characteristic of different species, even amongst our native plants, that the amount congenial to each varies considerably. Generally speaking, the succulent thick-leaved Plants require the largest amount; their stomata are few in number; and the full influence of light is requisite to induce sufficient activity in the exhaling process; accordingly we find them growing, for the most part, in exposed situations, where there is nothing to interfere with the full influence of the solar rays. On the other hand, plants with thinner and more delicate leaves, in which the exhaling process is easily excited to an excessive amount, evidently find a congenial home in more sheltered situations; and there are some which can only develop themselves in full luxuriance in the deep shades of a plantation or a forest. By a farther adaptation of the same kind, some species of Plants are enabled to live and acquire their green colour, under an amount of deprivation which would be fatal to most others; thus in the mines of Freyberg, in which the quantity of light admitted must be almost infinitesimally small, Humboldt met with Flowering-Plants of various species; and Mustard and Cress have been raised in the dark abysses of the colleries of this country.

92. Generally speaking, however, the Cryptogamia would seem to be better adapted than Flowering-Plants, to carry on their vegetating processes under a low or very moderate amount of this stimulus. Thus Humboldt found a species of Sea-weed near the Canaries, which possessed a bright grass-green hue, although it had grown at a depth of 190 feet in the sea, where, according to computation, it could have received only 1-1500th part of the solar rays that would have fallen upon it at the surface of the ocean. Many Ferns, Mosses, and Lichens seem as if they avoided the light, choosing the northern rather than the southern sides of hedges, buildings, &c., for their residence; so that the former often present a luxuriant growth of Cryptogamic vegetation, whilst the latter are comparatively bare. It must not be supposed, however, that they avoid light altogether, but only what is to them an excessive degree of it. The avoidance of light seems to be much stronger in the Fungi, which grow most luxuriantly in very dark situations; and the reason of this is probably to be found in the fact, that, like the germinating seed, they form rather than decompose carbonic acid; their food being supplied to them from the decaying substances on which they grow; and the rapid changes in their tissues giving rise to a high amount of Respiration,—a change exactly the converse of that, on which, as we have seen, Light exerts such a remarkable stimulating power.

93. In regard to the influence of Light upon the functions of Animals, comparatively little is certainly known. It is evident that the

influence it exerts on those chemical processes, which constitute the first stage of Vegetable nutrition, can have scarcely any place in Animals; because *they* do not perform any such acts of combination, but make use of the products already prepared for them by Plants. Hence we do not find that the *surface* of Animals undergoes that extension, for the purpose of being exposed to the solar rays, which is so characteristic a feature in the Vegetable fabric, and so important in its economy. Still there can be no doubt, that the degree of exposure to light has a great influence upon the *colours* of the Animal surface; and here we seem to have a manifestation of Chemical agency, analogous to that which gives colour to the Vegetable surface. Thus it is a matter of familiar experience, that the influence of light upon the skin of many persons, causes it to become spotted with brown *freckles;* these freckles being aggregations of brown pigment-cells, which either owed their development to the stimulus of light, or were enabled by its agency to perform a chemical transformation which they could not otherwise effect. In like manner, the swarthy hue which many persons acquire in warm climates, is due to a development of dark pigment-cells diffused through the epidermis; and an increased development of the same kind gives rise to the blackness of the Negro-skin. There can be no doubt that the prolonged influence of light upon one generation after another, tends to give a permanent character to this variety of hue; which will probably be more easily acquired, in proportion to the previously-existing tendency to that change. Thus it is well known that a colony of Portuguese Jews, which settled at Tranquebar about three centuries ago, and which has kept itself distinct from the surrounding tribes, cannot now be distinguished, as to colour, from the native Hindoos. But it is probable that a similar colony of fair-skinned Saxons would not, in the same time, have acquired anything like the same depth of colour in their skins.

94. There can be no doubt that the brilliancy of colour, which is characteristic of many tribes of animals in tropical climates, especially Birds and Insects, is in great part dependent, like the brightness of the foliage and fruit of the same countries, upon the brightness of the light to which their surfaces are exposed. When birds of warm climates, distinguished by the splendour of their plumage, are reared under an artificial temperature in our own country, it is uniformly observed that they are much longer in acquiring the hues characteristic of the adult; and that these are never so bright, as when they have been produced by the influence of the tropical sun. And it has been also remarked, that if certain Insects (the Cockroach for example), which naturally inhabit dark places, be reared in an *entire* seclusion from light, they grow up almost as colourless as Plants that are made to vegetate under similar circumstances.

95. There is abundant proof that Light exercises an important influence on the processes of *development* in Animals, no less than in Plants. Thus, the appearance of Animalcules in infusions of decaying organic matter is much retarded, if the vessel be altogether secluded

from it. The rapidity with which the small Entomostracous Crustacea (Water-Fleas, &c.), of our pools, undergo their transformations, has been found to be much influenced by the amount of light to which they are exposed. And it has been ascertained that, if equal numbers of Silk-worm's eggs be preserved in a dark room, and exposed to common daylight, a much larger proportion of larvæ are hatched from the latter than from the former.—The most striking proof of the influence of Light on animal development, however, is afforded by the experiments of Dr. Edwards. He has shown that, if Tadpoles be nourished with proper food, and be exposed to the constantly-renewed contact of water (so that their respiration may be freely carried on, whilst they remain in their Fish-like condition), but be entirely deprived of light, their growth continues, but their metamorphosis into the condition of air-breathing animals is arrested, and they remain in the condition of large tadpoles.—Numerous facts, collected from different sources, lead to the belief that the healthy development of the Human body, and the rapidity of its recovery from disease, are greatly influenced by the amount of light to which it has been exposed. It has been observed, on the one hand, that a remarkable freedom from deformity exists amongst nations who wear very little clothing; whilst, on the other, it appears certain that an unusual tendency to deformity is to be found among persons brought up in cellars or mines, or in dark and narrow streets. Part of this difference is doubtless owing to the relative purity of the atmosphere in the former case, and the want of ventilation in the latter; but other instances might be quoted, in which a marked variation presented itself, under circumstances otherwise the same. Thus, it has been stated by Sir A. Wylie (who was long at the head of the medical staff in the Russian army), that the cases of disease on the dark side of an extensive barrack at St. Petersburgh, have been uniformly, for many years, in the proportion of three to one, to those on the side exposed to strong light. And in one of the London Hospitals, with a long range of frontage looking nearly due north and south, it has been observed that residence in the south wards is much more conducive to the welfare of the patients, than in those on the north side of the building.

96. These facts being kept in view, it is easy to perceive that there must be differences among the various species of Animals, as among those of Plants, in regard to the degree of light which is congenial to them. Among the lowest tribes, in which no special organs of vision exist, there is evidently a susceptibility to the influence of light, which appears scarcely to deserve the name of sensibility, but which seems rather analogous to that which is manifested by Plants; thus among those Polypes which are not fixed to particular spots, and amongst Animalcules, there are some species which seek the light, and others which shun it. And it appears from various observations upon the depths at which marine animals are found, especially from the extensive series of facts collected by

Prof. E. Forbes,* that there are a series of *zones*, so to speak, to be met with in descending from the surface towards the bottom of the ocean, each of which is characterized by certain species of animals peculiar to itself, whilst other species have a range through two or more of the zones;—the extent of the range of depth, in each species, bearing a close correspondence with the extent of its geographical distribution. Now there can be no doubt, that the restriction of particular species to particular zones is due in great part to the degree of *pressure* of the surrounding medium; but there can be as little doubt, that the variation in the degree of light also exerts a most important influence, the solar rays in their passage through sea water being subject to a loss of one half for every seventeen feet. From the results of Prof. Forbes' researches, it appears that no species of Invertebrated animals habitually live at a greater depth than 300 fathoms; and although Fishes have been captured at a depth of from 500 to 600 fathoms, it is probable that they had strayed from their usual abodes. It is interesting to remark, that the *Proteus anguineus*, an animal which closely corresponds in its fully-developed form with the transition stage between the Tadpole and the Frog, finds a congenial abode in the dark lakes of the caverns of Styria and Carniola, and in the underground caverns that connect them;—thus showing its adaptation to a condition, which keeps down to the same standard the development of an animal, that is empowered under other circumstances to advance beyond it.

2. *Of Heat, as a Condition of Vital Action.*

97. The most perfectly-organized body, supplied with all the other conditions requisite for its activity, must remain completely inert, if it do not receive sufficient stimulation from Heat. The influence which this agent exerts upon living beings, is far more remarkable than its effects upon inorganic matter; although the latter are usually more obvious. We are all familiar with its power of producing expansion,—with the liquefaction which is the consequence of its application to solids,—with the evaporation which it occasions in liquids,—and with the enormous repulsive force which it generates among the particles of vapours; but it is not until we look deeper than the surface, that we perceive how immediate is the dependence of every action of Life upon this mysterious agent. The temporary or permanent loss of vitality, in parts of the body subjected to extreme cold, is a "glaring instance" of the effect of its withdrawal. This change, however, is not immediate. Its first step is a mere depression of the vitality of the part, involving a partial stagnation of the capillary circulation, diminution of sensibility, and want of muscular power. But the continued action of cold on the surface, not compensated by a sufficient generation of heat within, causes the circulation of the

* Report on the Invertebrata of the Ægean Sea, in Transactions of British Associations, 1843.

part to be completely suspended; its small vessels contract so that they become almost emptied of blood, its sensibility and power of movement are destroyed,—in a word, its vitality is completely suspended. In such a state, a timely but cautious application of warmth may produce the gradual renewal of the circulation, and the restoration of the other properties of the part, which are dependent upon that function; but any abrupt change would complete the mischief which the cold has begun; and would altogether destroy, by the violence of the reaction, the vitality which was only suspended, causing the actual *death* of the part. Hence, when the extremities are frost-bitten, nothing can be more injurious than to bring them near a fire; whilst no treatment has been found so safe and effectual, as the rubbing them with snow.

98. The influence of Heat upon Vital activity, is attested on a larger scale, by the striking contrast between the dreary barrenness of Polar regions, and the luxuriant richness of Tropical countries, where almost every spot teems with Animal and Vegetable life. And the alternation of Winter and Summer in temperate climates, may be almost said to bring under our own view the opposite conditions of those two extreme cases. The effect of the withdrawal of Heat is most obvious in the Vegetable kingdom; since all its operations are dependent upon a certain supply of that agent; and in no case are Plants possessed of the power of generating that supply within themselves,—excepting in certain organs which do not impart it to the rest of the structure. When the temperature of the air falls to the freezing-point, therefore, we find all the operations of the Vegetable economy undergoing a complete suspension; yet a very trifling rise will produce a renewal of them. It is not only in Evergreens, that the vital processes continue to be performed to a certain extent during the winter; for there is abundant evidence that, even in the trunk and branches of trees unclothed with leaves, a circulation of sap takes place, whenever there is even a slight return of warmth. In this manner, the leaf-buds are gradually prepared during the milder days of winter, so as to be ready to start forth into full development, with the returning steady warmth of spring.

99. The influence of Heat upon Vegetation is easily made apparent by experiment; in fact experimental illustrations of it, on a large scale, are daily in progress. For the Gardener, by artificial warmth, is not only enabled to rear with success the plants of tropical climates, whose constitution would not bear the chilling influence of our winter; but he can also, in some degree, invert the order of the seasons, and produce both blossom and fruit from the plants of our own country, when all around seems dead. This process of *forcing*, however, is unfavourable to the health and prolonged existence of the plants subjected to it; since the period of repose, which is natural to them, is interrupted; and they are caused, as it were, to live too fast. The same result occurs, when a plant or tree of temperate climates is transported to the tropics. Within a very short period after one crop

of leaves has fallen off, a new one makes its appearance. This goes through all its changes of development and decay more rapidly than it would do in its native clime; and in its turn falls off, and is speedily succeeded by another. Hence the fruit-trees of this country, transported to the East or West Indies, bear abundant crops of leaves,—three, perhaps, in one year, or five in two years,—but little or no fruit; and the period of their existence is much shortened.

100. As Plants are almost wholly dependent upon the temperature of the surrounding medium, for the supply of Heat necessary for their growth, many regions must have been devoid of Vegetable life altogether; if there were not a remarkable adaptation, in the wants of different species, to the various degrees of temperature of the habitations prepared for them. Thus we see the Cacti and Euphorbiæ attaching themselves to the surface of the most arid rocks of tropical regions, luxuriating, as it would seem, in the full glare of the vertical sun, and laying up a store of moisture from the periodical rains, of which even a long-continued drought is not sufficient to deprive them. The Orchideous tribe, on the other hand, whose greatest development occurs in the same zone, find their congenial habitation in the depths of the tangled forests, where, with scarcely an inferior amount of heat, they have the advantage of a moister atmosphere, caused by the exhalations of the trees on which they cling. The majestic Tree-Fern, again, reaches its full development in insular situations; where, with a moist atmosphere, it can secure a greater equability of temperature than is to be met with in the interior of the vast tropical continents. None of these races can develop themselves elsewhere, to their full extent, at least, unless their natural conditions of growth are imitated as far as possible; and in proportion as this imitation can be made complete, in that proportion may the plant of the tropics be successfully reared in temperate regions.

101. There are some examples of the adaptation of particular forms of Vegetable life to extremes of temperature, which are interesting as showing the extent to which this adaptation may be carried. In hot springs near a river of Louisiana, of the temperature of from 122° to 145°, there have been seen to grow not merely Confervæ and herbaceous plants, but shrubs and trees; and a hot-spring in the Manilla islands, which raises the thermometer to 187°, has plants flourishing in it, and on its borders. A species of *Chara* has been found growing and reproducing itself in one of the hot-springs of Iceland, which boiled an egg in four minutes; various Confervæ, &c., have been observed in the boiling-springs of Arabia and the Cape of Good Hope; and at the island of New Amsterdam, there is a mud-spring, which, though hotter than boiling-water, gives birth to a species of Liverwort. On the other hand, there are some forms of Vegetation, which seem to luxuriate in degrees of cold, that are fatal to most others. Thus the Lichen, which serves as the winter food of the Rein-deer, spreads itself over the ground whilst thickly covered with snow; and the beautiful little *Protococcus nivalis*, or Red Snow,

reddens extensive tracts in the arctic regions, where the perpetual frost of the surface scarcely yields to the influence of the solar rays at Midsummer.

102. It is, for the most part, among the Cryptogamic tribes,—the Ferns, Mosses, Liverworts, Fungi, and Lichens,—that the greatest power of growing under a low temperature exists; and we accordingly find that the proportion of these to the Phanerogamia, or Flowering Plants, increases as we proceed from the Equator towards the Poles. It has been estimated by Humboldt, that, in Tropical regions, the number of species of Cryptogamia is only about *one-tenth* that of the Flowering Plants; in the part of the Temperate zone which lies between Lat. 45° and 52°, the proportion rises to *one-half;* and the relative amount gradually increases as we proceed towards the Poles, until, between Lat. 67° and 70°, the number of species of Cryptogamia *equals* that of the Phanerogamia. Among the Flowering Plants, moreover, the greatest endurance of cold is to be found in those, which approach most nearly to the Cryptogamia in the low degree of their development; thus the Glumaceous group of Endogens, including the Grasses, Rushes, and Sedges, which forms about *one-eleventh* of the whole amount of Phanerogamic vegetation in the Tropics, constitutes *one-fourth* of it in the Temperate regions, and *one-third* in the Polar; and the ratio of the Gymnospermic group of Exogens, which chiefly consists of the Pine and Fir tribe, increases in like manner. Still the influence of a high temperature is evident even upon the Cryptogamia and their allies; for it is only under the influence of the light and warmth of tropical climes, that the Ferns, —the highest among the former,—can develop a woody stem, and assume the character of trees; and it is only there that the tall Sugar-Canes, and the gigantic Bamboos, which are but Grasses on a large scale, can flourish.

103. It appears, then, that to every species of Vegetable there is a temperature which is most congenial, from its producing the most favourable influence on its general vital actions. There is a considerable difference between the power of *growing*, and of *flourishing*, at a given temperature. We may lower the heat of a plant to such a degree, as to allow it to continue to live; yet its condition will be unhealthy. It absorbs food from the earth and air, but cannot assimilate and convert it. Its tissue grows but becomes distended with water, instead of being rendered firm by solid deposits. The usual secretions are not formed; flavour, sweetness, and nutritive matter, are each diminished; and the power of flowering and producing fruit is lost. We see a difference in the amount of heat required for the vegetating processes, even in the various species indigenous to our own climate; thus the common Chickweed, Groundsel, and Poa annua evidently grow readily at a temperature but little above the freezing-point, whilst the Nettles, Mallows, and other weeds around them, remain torpid. But the difference is much more strongly marked in the vegetation of different climates; showing an evident adaptation

of the tribes indigenous to each, to that range of temperature which they will there experience. Instead of being scantily supplied with such of the tropical plants as could support a stunted and precarious life in ungenial climates, the temperate regions are stocked with a multitude of vegetables which appear to be constructed expressly for them; inasmuch as these species can no more flourish at the Equator, than the equatorial species can in these Temperate regions. And such new supplies, adapted to new conditions, recur perpetually as we advance towards the apparently frozen and untenantable regions in the neighbourhood of the Pole. Every zone has its peculiar vegetables; and while we miss some, we find others making their appearance, as if to replace those which are absent.

104. Thus in the countries lying near the Equator, the vegetation consists in great part of dense forests of leafy evergreen trees, Palms, Bamboos, and Tree-Ferns, bound together by clustering Orchideæ and strong creepers of various kinds. There are no verdant meadows, such as form the chief beauty of our temperate regions; and the lower orders of Vegetation are extremely rare. It is only in this torrid Zone, that Dates, Coffee, Cocoa, Bread-fruit, Bananas, Cinnamon, Cloves, Nutmegs, Pepper, Myrrh, Indigo, Ebony, Logwood, Teak, Sandal-wood, and many other of the vegetable products, most highly valued for their flavour, their odour, their colour, or their density, come to full perfection. As we recede from the Equator, we find the leafy Evergreens giving place to trees with deciduous leaves; rich meadows appear, abounding with tender herbs; the Orchideæ no longer find in the atmosphere, and on the surface of the trees over which they cluster, a sufficiency of moisture for their support, and the parasitic species are replaced by others which grow from fleshy roots implanted in the soil; but aged trunks are now clothed with Mosses; decayed vegetables are covered with parasitical Fungi; and the waters abound with Confervæ. In the warmer parts of the temperate regions, the Apricot, Citron, Orange, Lemon, Peach, Fig, Vine, Olive, and Pomegranate, the Myrtle, Cedar, Cypress, and Dwarf Palm, find their congenial abode. These give place, as we pass northwards, to the Apple, the Plum, and the Cherry, the Chestnut, the Oak, the Elm, and the Beech. Going further still, we find that the fruit-trees are unable to flourish, but the timber-trees maintain their ground. Where these last fail, we meet with extensive forests of the various species of Firs; the Dwarf Birches and Willows replace the larger species of the same kind; and even near or within the arctic circle, we find wild flowers of great beauty,—the Mezereon, the yellow and white Water-Lily, and the Globe-flower. Where none of these can flourish, where trees wholly disappear, and scarcely any flowering-plants are to be met with, an humbler Cryptogamic vegetation still raises its head, in proof that no part of the Globe is altogether unfit for the residence of living beings, and that the empire of Flora has no limit.

105. But distance from the Equator is by no means the only ele-

ment, in the determination of the mean temperature of a particular spot, and of the Vegetation which is congenial to it. Its height above the level of the sea is equally important; for this produces a variation in the amount of heat derived from the Sun, at least as great as that occasioned by difference of latitude. Thus it is not alone on the summits of Hecla, Mount Blanc, and other mountains of arctic or temperate regions, that we find a coating of perpetual snow; we find a similar covering on the lofty summits of the Himalayan chain, which extends to within a few degrees of the tropic of Cancer; and even on the higher peaks of that part of the ridge of the Andes, which lies immediately beneath the Equator. The height of the *snow-line* beneath the Equator, is between 15,000 and 16,000 feet above the level of the sea; on the south side of the Himalayan ridge, it is as much as 17,000 feet, but on the north side only 13,000 feet; and in the Swiss Alps it is about 8000 feet. Its position is very much affected, however, by local circumstances, such as the neighbourhood of a large expanse of land or of sea; hence the small quantity of land in the Southern Hemisphere, renders its climate generally so much colder than that of the Northern, that in Sandwich land (which is Lat. 59° S., or in the same parallel as the north of Scotland), the whole country, from the summits of the mountains down to the very brink of the sea-cliffs, is covered many fathoms thick with everlasting snow; and in the island of Georgia (which is in Lat. 54° S., or in the same parallel as Yorkshire,) the limit of perpetual snow descends to the level of the ocean, the partial melting in summer only disclosing a few rocks, scantily covered with moss and tufts of grass. Yet the highest mountains of Scotland, which ascend to an elevation of nearly 5000 feet, and are four degrees more distant from the equator, do not attain the limit of perpetual snow; this is reached, however, by mountains in Norway, at no greater elevation.

106. If, then, Temperature exert such an influence on Vegetation as has been stated, we ought to find on the sides of lofty mountains in tropical regions the same progressive alterations in the characters of the Plants that cover them, as we encounter in journeying from the equatorial towards the polar regions. This is actually the case. The proportion of Cryptogamia to Flowering Plants, for example, is no more than *one-fifteenth* on the *plains* of the Equatorial region; whilst it is as much as *one-fifth* on the *mountains*. In ascending the Peak of Teneriffe, Humboldt remarked as many as five distinct Zones, which were respectively marked by the products which characterize different climates. Thus at the base, the vegetation is altogether tropical; the Date-Palm, Plaintain, Sugar-Cane, Banyan, the succulent Euphorbia, the Dracœna, and other trees and plants of the torrid zone there flourish. A little higher grow the Olive, the Vine, and other fruit-trees of Southern Europe; there Wheat flourishes; and there the ground is covered with grassy herbage. Above this is the woody region, in which are found the Oak, Laurel, Arbutus, and other beautiful hardy evergreens. Next above is the region of Pines; charac-

terized by a vast forest of trees resembling the Scottish Fir, intermixed with Juniper. This gives place to a tract remarkable for the abundance of Broom; and at last the scenery is terminated by Scrofularia, Viola, a few Grasses, and Cryptogamic plants, which extend to the borders of the perpetual snow that caps the summit of the mountain.

107. The effects of Temperature on Vegetation are not only seen in its influence upon the Geographical distribution of Plants, that is, in the limitation of particular species to particular climates; for they are shown, perhaps even more remarkably, in the variation in the size of individuals of the same species; when that species possesses the power of adapting itself to widely-different conditions, which is the case with some. Thus the *Cerasus Virginiana* grows in the southern states of North America as a noble tree, attaining one hundred feet in height; in the sandy plains of the Saskatchawan, it does not exceed twenty feet; and at its northern limit, the Great Slave Lake, in Lat. 62°, it is reduced to a shrub of five feet. Another curious effect of heat is shown in its influence on the sexes of certain Monœcious flowers; thus Mr. Knight mentions that Cucumber and Melon plants will produce none but male or staminiferous flowers, if their vegetation be accelerated by heat; and all female or pistilliferous, if its progress be retarded by cold.

108. The injurious influence of excessive heat can be, to a certain extent, resisted by Plants, through the cooling process kept up by the continual evaporation of moisture from their surface. But the power of maintaining this cooling process entirely depends upon the supply of fluid, with which the plant is furnished. If the supply be adequate to the demand, the effect of heat will be to stimulate all the vital operations of the plant, and to cause them to be performed with increased energy; though, as we have already seen, this energy may be such as to occasion a premature exhaustion in its powers, by the excessive luxuriance which it occasions. But if the supply of water be deficient, the plant is burnt up by the continuance of heat in a dry atmosphere; and it either withers and dies, or its tissues become dense and contracted, without losing their vitality. Thus it has been remarked, that shrubs growing among the sandy deserts of the East, have as stunted an appearance as those attempting to vegetate in the Arctic regions; their leaves being converted into prickles, and their leaf-buds prolonged into thorns instead of branches.—The influence of excessive heat in destroying life, can sometimes be traced through the direct physical changes which it occasions in the vegetable tissues. Thus it has been ascertained that grains of corn will vegetate, after exposure to water or vapour possessing a considerable degree of heat; provided that heat do not amount to 144° in the case of water, and 167° in that of vapour. At these temperatures, the structure of the seed undergoes a disorganizing change, by the rupture of the vesicles of starch which form a large part of it; and the loss of its power of germinating is therefore readily accounted for. The highest temperature which

the soil usually possesses in tropical climates, is about 126°, though Humboldt has once observed the thermometer rise to 140°. Seeds imbedded in such a soil, therefore, may not lose their vitality, although they will not germinate in such temperatures. The temperature most favourable to germination probably varies in different species, and is one of the conditions that produces their adaptation to different climates. Thus it appears that Corn will not germinate in water at a higher temperature than 95°, whilst Maize will germinate in water at 113°; and, as is well known, Maize will flourish in countries in which Corn cannot be grown.

109. We must not confound the power which Plants possess of *vegetating*, or exhibiting *vital activity*, under widely-different degrees of temperature, with the power of retaining their *vitality* in a dormant condition, which many of them possess in a very remarkable degree. When the external temperature is much below the freezing-point, it is impossible that any vegetating processes can go on; since the Plant does not possess the power of generating heat within itself. Now such a complete cessation of activity is quite compatible, in many instances, with the preservation of the organized structure in a condition perfectly unchanged, and, in consequence, with the continuance of its peculiar properties; so that these properties may be again called into operation, when the temperature shall have risen. But in other cases, the plant may be *killed* by the intensity of the cold; that is, the return of warmth will not excite it to activity. We have occasion to notice, in every severe winter, the difference in this respect amongst the plants which are cultivated in our own climate; some of them being killed by a hard frost, the effects of which are resisted by others, even though their situation be more exposed. In general it will be found, that the cold acts most powerfully (as might be expected) upon plants which are not indigenous to our country, but which have been introduced and naturalized from some warmer regions. But it is worthy of note, amongst other peculiarities in the relation of Heat and Vegetation, that many plants are readily killed by a low temperature, which yet flourish well under a very moderate amount of warmth; so that they will grow in situations where the mean temperature of the year is low and the summers cool, provided the winters are not severe; whilst they cannot be preserved without special protection, in situations where the winters are colder, even though the summers should be much hotter, and the mean temperature of the whole year should be considerably higher. Thus there are shrubs growing in the Botanic Garden of Edinburgh, which cannot be safely left in the open air in the neighbourhood of London, and which would be most certainly killed by the winter-cold of central France.

110. It does not admit of doubt, that the destructive influence of a very low temperature upon the Vitality of Plants, is immediately exerted through its chemical and physical effects upon the tissues and their contents. Thus it will produce congelation of their fluids; and the expansion which takes place in freezing will injure the walls of

the containing cells,—distending, lacerating, or even bursting them. The same cause will probably occasion the expulsion of air from some parts which ought to contain it; and the introduction of it into other parts which ought to be filled with fluid. And a separation will take place, in the act of freezing, between the constituent parts of the vegetable juices; which will render them unfit for discharging their functions, when returning warmth would otherwise call them into activity. Hence we are enabled in some degree to account for the differences in the power of resisting cold, which the various species of Plants, and even the various parts of the same individual, are found to possess. For, other things being equal, the power of each plant, and of each part of a plant, to resist a low temperature, will be in the inverse ratio of the quantity of water contained in the tissue; thus, a succulent herbaceous plant suffers more than one with a hard woody stem and dense secretions; and young shoots are destroyed by a degree of cold, which does not affect old shoots and branches of the same shrub or tree. Again, the viscidity of the fluids of some plants is an obstacle to their congelation, and therefore enables them to resist cold; thus it is, that the resinous Pines are, of all trees, those which can endure the lowest temperature. The dimensions of the cells, too, of which the tissue is composed, appears to have an influence; the liability to freeze being diminished by a very minute subdivision of the fluids. And when the roots are implanted deep in the soil, where the temperature does not fall so low as that of the surface by many degrees, the fluidity of the sap may be maintained, in spite of an extremely cold state of the atmosphere.

111. It is in Cryptogamic plants, that the greatest power of sustaining cold exists; as might be inferred from what has been already stated in regard to their geographical distribution. The Little Fungus (*Torula Cerevisiæ*) which is one of the principal constituents of Yeast, does not lose its vitality by exposure to a temperature of 76° *below zero;* though it requires a somewhat elevated temperature for its active growth. It would appear that *Seeds* are enabled to sustain a degree of cold without the loss of their vitality, which would be fatal to growing plants of the same species; thus grains of corn, of various kinds, will germinate after being exposed for a quarter of an hour to a temperature equal to that of frozen mercury. It is not difficult to account for this, when the closeness of their texture, and the small quantity of fluid which it includes, are kept in view. The act of Germination, however, will only take place under a rather elevated temperature; and we find in the Chemical changes which it involves, a provision for maintaining this, when the process has once commenced.

112. The influence of Heat upon the vital activity of Animals, is quite as strongly marked as we have seen it to be in the case of Plants; but the mode in which it is exerted is in many instances very different. In those animals which are endowed with great energy of muscular movement, and in which, for the maintenance of that energy, the nutritive functions are kept in constant activity, we find that a provi-

sion exists for the development of heat from within, so as to keep the temperature of the body at a certain uniform standard, whatever may be the climate in which they live. Their energy and activity are, in fact, so dependent upon the steady maintenance of a high temperature in their bodies, that, if this be not kept up nearly to its regular standard, a diminution or even a complete cessation of vital action takes place, and even a total loss of vitality may result. In these *warm-blooded* animals, as they are termed, we do not so evidently trace the effects of Heat, because they are constantly being exerted, and because *external* changes have but little influence upon them, unless these changes are of an extreme kind. But if those *internal* operations, on which the maintenance of the temperature is dependent, are, from any cause, retarded or suspended, the effect is immediately visible in the depressed activity of the whole system. In the class of Birds whose muscular energy, and whose general functional activity, are greater and more constant than those of any other animals, the temperature is pretty steadily maintained at from 108° to 112°; and we shall presently see, that a depression of the heat of the body to about 80° is fatal. Among Mammalia, the temperature is usually maintained at from 98° to 102°; and it seems that here, too, a depression of about thirty degrees is ordinarily fatal.

113. In the different tribes of Birds and Mammals, we find a very diversified power of generating heat; and on this depends their adaptation to various climates. Where the usual temperature of the atmosphere is but little below the normal standard of the body, a small amount of the internal calorifying power is required; and accordingly we find that animals which naturally inhabit the torrid zone, cannot be kept alive elsewhere, except, like the Plants of the same regions, by external heat. On the other hand, the animals of the colder-temperate and frigid climes are endowed with a much greater internal calorifying power; and their covering is adapted to keep in the heat which they generate. Such animals (the Polar Bear, for example,) cannot be kept in health, in the summer of our own country, unless means are taken for their refrigeration. The constitution of man seems to acquire, by habituation to a particular set of conditions through successive generations, an adaptation to differences of climate, of which that of few other animals is susceptible; and thus we find different races of human beings inhabiting countries, which are subject to the extremes of heat and cold. The Hindoo or the Negro, suddenly transported to Labrador or Siberia during the depth of winter, would probably sink in the course of a few days, from want of power to generate within his body a sufficient amount of heat to resist the depressing influence of the external cold; whilst, on the other hand, the Esquimaux, suddenly conveyed to the hottest parts of India or Africa, would speedily become the subject of disease, which would probably terminate his life in a short time. It is in the inhabitant of temperate climates, who is naturally exposed during the seasonal changes of his year, to a wide range of external temperature, that we find the greatest power of

sustaining the extremes of either cold or heat; and yet, even in such, the continued exposure to either extreme during a long series of years, will so much influence the heat-producing power, that the constitution does not adapt itself readily to a change of conditions.

114. We see, then, that the variations observable between different races in this respect, are only exaggerations (so to speak) of the alternations which an individual may undergo in the course of a few years; and it is easy to understand how such an adaptation may take place to an increased extent in successive generations;—this being the regular law, not merely in regard to Man, but in regard to other animals placed under new conditions, to which they have a certain, but limited, power of adapting themselves. Thus we find that an European, who has lived for several years in the East or West Indies, suffers considerably from the cold, when he first returns to winter in his native country: his constitution having, for a time, lost some of its power of generating heat. After a few years' residence, however, this power is commonly recovered to its original extent, unless the age of the individual be too far advanced; but his children, if they have been not only born, but brought up, in the hotter climate, experience much greater difficulty in adapting themselves to the colder one.

115. The conditions on which the power of maintaining the heat of the body, in despite of external cold, is dependent, will become the subject of inquiry hereafter (Chap. X). It is sufficient here to state, that this power is the result of numerous Chemical changes going on within the body; and especially of a process analogous to combustion, in which carbon and hydrogen, taken in as food, are made to unite with oxygen derived from the atmosphere. It is dependent, therefore, as to its amount, upon the due supply of the combustible material on the one hand, and of atmospheric air on the other. If the former is not furnished, either by the food or by the fatty matter of the body, (which acts as a kind of reserved store laid up against the time of need,) the heat cannot be maintained; and it is in part for want of power to digest and assimilate a sufficient amount of this kind of aliment, that animals of warm climates cannot maintain their temperature in colder regions. On the other hand, if the supply of oxygen be deficient, as it is when the respiration is impeded by diseased conditions of various kinds, there is a similar depression of temperature.

116. Now, if, from either of these causes, the temperature of the body of a Bird or Mammal (except in the case of the *hybernating* species of the latter, to be presently noticed) be lowered to about 30° below its usual standard, not only is there a cessation of vital *activity*, but a total loss of vital *properties;* in other words, the *death* of the animal is a necessary result. This occurrence is preceded by a gradually-increasing torpidity; which shows the depressing influence of the cooling process upon the functions in general. The temperature of the superficial parts of the body is, of course, first affected; the circulation is at first retarded, causing lividity of the skin; but, as the tem-

perature becomes lower, the blood is almost entirely expelled from the surface, by the contraction of the vessels, and paleness succeeds. At the same time, there is a gradually-increasing torpor of the nervous and muscular systems, which first manifests itself in an indisposition to exertion of any kind, and then in an almost irresistible tendency to sleep. At the same time, the respiratory movements become slower, from the want of the stimulus that should be given by the warm current of blood to the medulla oblongata, which is the centre of those movements; and the loss of heat goes on, therefore, with increased rapidity, until the temperature of the whole body is so depressed, that its vitality is altogether destroyed.

117. But when there is a deficiency of the proper *animal* heat, the vital activity of the system may be maintained by caloric supplied by external sources. This fact is of high scientific value, as giving the most complete demonstration of the *immediate* dependence of the vital functions of warm-blooded animals upon a sustained temperature; and its practical importance can scarcely be overrated. It rests chiefly upon the recent experiments of Chossat, who had in view to determine the circumstances attending death by Inanition or starvation. He found that, when Pigeons were entirely deprived of food and water, their average temperature underwent a tolerably regular diminution from day to day; so that, after several days, (the exact number varying with their previous condition,) it was about $4\frac{1}{2}°$ lower than at first. Up to this time, it seems that the store of fat laid up in the body supplies the requisite material for the combustive process; so that no very injurious depression of temperature occurs. But, as soon as this is exhausted, the temperature falls rapidly, from hour to hour; and as soon as the total depression has reached $29\frac{1}{2}°$ or $30°$, death supervenes. Yet it was found by M. Chossat, that when animals thus reduced by starvation, whose death seemed impending, (death actually taking place, in many instances, whilst the preliminary processes of weighing, the application of the thermometer, &c., were being performed,) were subjected to artificial heat, they were almost uniformly restored, from a state of insensibility and want of muscular power, to a condition of comparative activity. Their temperature rose, their muscular power returned, they took food when it was presented to them, and their secretions were renewed; and, if this artificial assistance was sufficiently prolonged, and they were supplied with food, they recovered. If the heat was withdrawn, however, before the time when the digested food was ready, in sufficient amount, to supply the combustive process, they still sank for want of it.

118. Various important practical hints may be derived from the consideration of these facts. There can be no doubt that, in many diseases of exhaustion, the want of power to sustain the requisite temperature, is the *immediate* cause of death; the whole combustible material of the body having been exhausted, and the digestive apparatus not being able to supply what is required. Now where this is the case, there is no doubt that life may be prolonged, and that

recovery may be favoured, by the judicious sustentation of the temperature of the body. This may be effected either by internal or by external means. Of the internal, the most efficient is undoubtedly the administration of alcoholic fluids; which, for reasons hereafter to be given, (§ 496,) will be absorbed into the circulating system, when no other alimentary substance can be taken in; and which, moreover, exert a favourable influence by their specific stimulating effect upon the nervous system. It is a matter of familiar experience, that in such conditions of the body, the quantity of alcohol which may be administered with positive and evident benefit, is such as would in ordinary circumstances be productive of the most injurious results; and this is fully accounted for by the reflection, that it is *burnt off* as fast as it is taken in. But a most important adjunct in all such cases, —and in many instances a substitute for alcohol, when the latter would be inadmissible,—will be found in the application of *external* heat; and especially in the subjection of the whole surface to its influence, by means of the hot-air bath. This is a valuable portion of the treatment, in the recovering of persons who have been reduced to insensibility by suffocation of any kind; and especially in cases of drowning, since the heat of the body is rapidly withdrawn by the conducting power of the water. Indeed it may be stated as a general rule, that, where the temperature of the body is lowered from any cause, *external heat* may be advantageously applied; and much evidence has lately been produced to show, that the reparative processes by which extensive wounds are healed, go on more favourably under the contact of warm, dry air, than with any other application.

119. On the other hand, where the object is to keep down a tendency to a too violent action, the local application of moderate *cold* is found to be of the greatest value; all surgeons of eminence being now agreed upon the efficacy of *water-dressing* in restraining the inflammatory process, especially in cases of wounds of the joints, in which this action is most to be apprehended. The *general* application of cold to the surface, by means of continued exposure to cool air, or by a short immersion in cold water, is frequently in the highest degree beneficial, by imparting *tone* to the system, *i.e.*, by producing a firmer condition in the solids which were previously relaxed, and more especially by calling into action the *tonicity* of the walls of the blood-vessels, which imparts to them an increased resistance, and thus favours the regular and vigorous circulation of blood, upon principles which will be hereafter stated (§ 609). But so far from producing any permanent depression in the temperature of the body, this measure has a tendency to elevate it, by the increased vigour it produces in the circulation; hence the glow which is experienced after the use of the cold bath. If this effect be *not* produced, and a chilling of the body, instead of an invigorating warmth, be the result of the use of cold, it is evident that this cannot be beneficial. The injurious results of the too-prolonged application of even a moderate degree of cold, are seen in the depression of temperature, without a

corresponding reaction, which is the consequence of an immersion in water of 50° or 55° prolonged for several hours; and still more in that chilling of the whole surface frequently productive of the most serious consequences, which arises from the evaporation of fluid from garments that have been moistened, either by perspiration from within, or by the fall of rain or dew upon their exterior. There is no doubt that the obstruction to the continuance of the perspiration, presented by a covering already saturated with moisture, is one cause of the injurious results that so commonly follow such an occurrence; but there is as little doubt that the chilling influence of the external evaporation has a large share in producing them. For experience shows that, if the evaporation be prevented by an impenetrable covering, the contact of a garment thoroughly saturated with moisture is not productive of the same injurious consequences.

120. The practical importance of the due comprehension of the principles upon which heat and cold should be employed, in the treatment of disease and the preservation of health, has required this digression. We now proceed to consider the influence of temperature upon a certain group of warm-blooded animals; which offers a remarkable peculiarity in this respect,—their power of generating heat being for a time greatly diminished or almost completely suspended; the temperature of their bodies following that of the air around, so that it may be brought down nearly to the freezing-point; their general vital actions being carried on with such feebleness as to be scarcely perceptible; and yet the vital properties of the tissues being retained, so that, when the temperature of the body is again raised, the usual activity returns. This state, which is called *hybernation*, appears to be as natural to certain animals, as sleep is to all; and it corresponds with sleep in its tendency to periodical return.

121. No account can be given of the causes to which it is due; but the condition of the animals presenting it offers several points of much interest. There are some, as the *Lagomys*, in which it appears to differ but little from deep ordinary sleep; they retire into situations which favour the retention of their warmth; and they occasionally wake up, and apply themselves to some of the store of food, which they have provided in the autumn. In other cases, a great accumulation of fat takes place within the body in autumn, favoured by the oily nature of the seeds, nuts, &c., on which the animals then feed; and this serves the purpose of maintaining the temperature for a sufficient length of time, not indeed to the usual standard, but to one not far below it. The state of torpor in these animals is more profound than that of deep sleep, but it is not such as to prevent them from being easily aroused; and their respiratory movements, though diminished in frequency, are still performed without interruption. But in the *Marmot*, and in animals which, like it, hybernate completely, the temperature of the body (owing to the want of internal power to generate heat) and the general vital activity, are propor-

tionably depressed; the respiratory movements fall from 500 to 14 per hour, and are performed without any considerable enlargement of chest; the pulse sinks from 150 to 15 beats per minute; the state of torpidity is so profound that the animal is with difficulty aroused from it; and the heat of the body is almost entirely dependent upon the temperature of the surrounding air, not being usually more than a degree or two above it. When the thermometer in the air is somewhat below the freezing-point, that placed within the body falls to about 35°; and at this point it may remain for some time without any apparent injury to the animal, as it revives when subjected to a higher temperature. When, however, the body is exposed to a more intense degree of cold, the animal functions undergo a temporary renewal; for the cold seems to act like any other stimulus in arousing them. The respiratory movements and the circulation increase in activity, so as to generate an increased amount of heat; but this amount is insufficient to keep up the temperature of the body, which is at last depressed to a degree inconsistent with the maintenance of life; and not only the suspension of activity, but the total loss of vital properties is the result.

122. Now the condition of a hybernating Mammal closely resembles that of a cold-blooded animal, in regard to the dependence of its bodily temperature upon external conditions. There is this important difference, however;—that the reduction of the temperature of the former to 60° or 50° is incompatible with a state of activity, which is only exhibited when the temperature rises to nearly the usual Mammalian standard;—whilst a permanently low or moderate temperature is natural to the bodies of most cold-blooded animals, whose functions could not be well carried on under a higher temperature. Thus all the muscles of a Frog are thrown into a state of permanent and rigid contraction, by the immersion of its body in water no warmer than the blood which naturally bathes those of the Bird; and we find, accordingly, that cold-blooded animals which cannot sustain a high temperature, are provided with a *frigorifying* rather than with a *calorifying* apparatus. Although we are accustomed to rank all animals, save Birds and Mammals, under the general term *cold-blooded*, yet there exist among them considerable diversities as to the power of generating heat within themselves, and of thus rendering themselves independent of external variations. Thus among Reptiles, it appears that there are some which can sustain a temperature several degrees above that of the atmosphere, especially when the latter is sinking; and among Fishes it is certain that there are species,—the *Tunny* and *Bonito*, for example,—which are almost entitled to the name of warm-blooded animals, their temperature being kept up to nearly 100°, when that of the sea is about 80°. It is uncertain, however, to what extent it would be depressed, by a lowering of that of the surrounding medium. The greatest power of developing heat in cold-blooded animals appears to exist, when their bodies are reduced nearly to the freezing-point, and when that of the surrounding air or water is much

below it. Thus Frogs have been found alive in the midst of ice whose temperature was as low as 9°, the heat of their own bodies being 33°; and it has been observed that even Animalcules contained in water that is being frozen, are not at once destroyed, but that each lives for a time in a small uncongealed space, where the fluid seems to be kept from solidifying by the caloric liberated from the Animalcule.

123. The peculiar condition of the class of Insects, in regard to its heat-producing power, exhibits in a very striking manner the connection between an elevated temperature and vital activity. In the *Larva* state of Insects, the temperature of the animal follows closely that of the surrounding air, as in the cold-blooded classes generally; but it is usally from ½° to 4° above it. In the *Pupa* condition, which is one of absolute rest in all insects that undergo a complete metamorphosis, the temperature scarcely rises above that of the surrounding medium; except nearly at the close of the period, when it is about to burst its envelops and to come forth as the perfect Insect. The elevation of temperature which different Insects present, varies in part according to the species, and in part with the condition of the individual in regard to rest or activity; but the same principle is evidently operating in both cases, since the variation existing amongst different species, in regard to their heat-producing power, is closely connected with the amount of activity natural to them. The highest amount is to be found in the industrious Hive-Bee and its allies, and in the elegant and sportive Butterflies, which are almost constantly on the wing in search of food; next to these come the Beetles of active flight; and lastly those which seldom or never raise themselves upon the wing, but pursue their labours on the ground. The temperature of individual Bees has been found to be about 4° above that of the atmosphere, when they are in a state of repose; but it rises to 10° or 15° when they are excited to activity. When they are aggregated together in clusters, however, the temperature which they possess is often as much as 40° above that of the atmosphere. When reduced to torpidity by cold, they still generate heat enough to keep them from being frozen, unless the cold be very severe; and they may be aroused by moderate excitement to a state of activity, in which the temperature rises to a very considerable height. Now although the increased production of heat is in these cases, as in hybernating Mammals, similarly aroused, the *consequence* of the increased activity, there can be no question that it is a condition necessary to the *continuance* of that activity; since we find that, if the temperature of the body be again reduced by external cold, the activity cannot be long maintained.

124. Whilst the foregoing facts exhibit the connection between an elevated temperature, and the most active condition of the muscular and nervous systems, in cold-blooded animals, there is abundant evidence of the same kind in regard to the influence of heat upon the processes of nutrition and development. Thus the time of emersion

of Insect-larvæ from their eggs,—or in other words, the rate at which the previous formative processes go on, is entirely dependent upon the temperature. In the case of the Bird we find that, if the temperature be not sufficient to develop the egg, chemical changes soon take place, which involve the loss of its vitality; or if the temperature be reduced so low as to prevent the occurrence of those changes, the loss of heat is in itself destructive of life. But this is not the case in regard to the eggs of cold-blooded animals in general; for, like the beings they are destined to produce, they may be reduced to a state of complete inaction by a depression of the external temperature; whilst a slight elevation of this renews their vital operations, at a rate corresponding to the warmth supplied. Hence the production of larvæ from the eggs of Insects may be accelerated or retarded at pleasure; and this is, in fact, practised in the rearing of Silk-worms, in order to adapt the time of their emersion from the egg to the supply of food which is ready for them. The same may be said in regard to the eggs of other cold-blooded animals; those, for example, of the minute Entomostracous Crustacea (Water-Fleas, &c.,) which people our ditches and ponds. In many of these, the race is continued solely by the eggs, which remain dormant through the winter; all the parents being destroyed by the cold. The common *Daphnia pulex* produces two kinds of eggs; from one, the young are very speedily hatched: but the others, which are produced in the autumn, and enveloped in a peculiar covering, do not give birth to the contained young until the succeeding spring. They may be at any time hatched, however, by artificial warmth.

125. We sometimes find special provisions, for imparting to the eggs a temperature beyond that which is natural to the bodies of the parents; thus it has been lately shown that in Serpents, the temperature of the posterior part of the body rises considerably, when the eggs are lying in the oviduct, preparatory to being discharged,—evidencing a special heat-producing power in the surrounding parts at this period, which is obviously for the purpose of aiding the maturity of the eggs. The Viper, whose eggs are frequently hatched in the maternal oviduct, so that the young are brought forth alive, is occasionally seen basking in the sun, in such a position as to receive its strongest heat on the parts that cover the oviduct. Certain Birds have recourse to substitutes for the usual method of incubation. The *Tallegalla* of New Holland is directed by its remarkable instinct, not to sit upon its eggs, but to bring them to maturity by depositing them in a sort of hot-bed, which it constructs of decaying vegetable matter. The Ostrich is believed to sit upon its eggs, when the temperature falls below a certain standard, but to leave them to the influence of the solar heat when this is sufficient to bring them to maturity; and this statement derives confirmation from a similar fact observed in a Fly-catcher, which built in a hot-house during several successive years,—the bird quitting its eggs when the temperature was high, and resuming its place when it fell. In all these cases, as in many more

which might be enumerated, we observe the influence of an elevated temperature upon the processes of development; and the provisions made by Nature, in the physical or mental constitution of animals, for affording that influence. The development of heat around the oviduct of the Serpent is a process over which the individual has no control, being entirely dependent upon certain Organic changes; whilst the imparting of warmth to its eggs by the Bird, either from its own body or through artificial means, is committed to the guidance of its Instinct,—which same instinct leads it to suspend the process when it is not necessary.

126. Phenomena of an equally interesting and instructive character may be observed in the history of the Pupa state of Insects; which, in those that undergo a complete metamorphosis, may be almost characterized as a re-entrance into the egg. In fact we shall obtain the most correct idea of the nature of that metamorphosis, by considering the Larva as an embryo, which comes forth from the egg in a very early and undeveloped condition, for the sake of obtaining materials for its continued development, which the egg does not supply in sufficient amount. When these have been digested and stored up in the body, the animal becomes completely inactive, so far as regards its external manifestations of life; and it forms some kind of envelop for its protection, which may not be unaptly compared to the shell or horny covering of the egg. Within this are gradually developed the wings, legs, and other parts which are peculiar to the perfect Insect; whilst even those organs, which it possesses in common with the Larva, are for the most part completely altered in character. When this process of development is completed, the Insect emerges from its Pupa case, just as the Bird comes forth from the egg; then only does its Insect life begin, its previous condition having been that of a Worm; and the alteration of its character is just as evident in its instinctive propensities, as it is in its locomotive and sensorial powers.

127. Now this process of development is remarkably influenced by external temperature; being accelerated by genial warmth, and retarded by cold. There are many Larvæ, which naturally pass into the Pupa state during the autumn, remain in it during the entire winter, and emerge as perfect Insects with the return of spring. It was found by Reaumur, that Pupæ, which would not naturally have been disclosed until May, might be caused to undergo their metamorphosis during the depth of winter, by the influence of artificial heat; whilst, on the other hand, their change might be delayed a whole year beyond its usual time, by the prolonged influence of a cold atmosphere. In order to hasten the development of the pupæ of the Social Bees, a very curious provision is made. There is a certain set, to which the name of Nurse-bees has been given, whose duty it is to cluster over the cells in which the Nymphs or Pupæ are lying, and to communicate the heat to them, which is developed by the energetic movements of their own bodies, and especially by respiratory actions of extreme rapidity. The nurse-bees begin to crowd

upon the cells of the nymphs, about ten or twelve hours before these last come forth as perfect Bees. The incubation (for so it may be called) is very assiduously persevered in during this period by the Nurse-bees; when one quits the cell, another takes its place; and the rapidity of the respiratory movements increases, until they rise to 130 or 140 per minute, so as to generate the greatest amount of heat just before the young bees are liberated from the combs. In one instance, the thermometer introduced among seven nursing-bees stood at $92\frac{1}{2}°$; the temperature of the external air being 70°. We observe in this curious propensity a manifest provision for accelerating the development of the perfect Insect, which requires (as already pointed out) a higher temperature than the larva, in virtue of its greater activity. The Nurse-bees do not station themselves over the cells which are occupied by the larvæ; nor do they incubate the nymph-cells with any degree of constancy and regularity, until the process of development is approaching its highest point.

128. We have seen that the animals termed *cold-blooded* are greatly influenced as to the temperature of their bodies, by the temperature of the surrounding medium; although many of them are endowed with the power of keeping themselves a certain number of degrees above it. Now the consequence of this is, that all of them which are subject to any considerable and prolonged amount of cold, pass into a state of more or less complete inactivity during its continuance; which state bears a close correspondence with the hybernation of certain Mammalia. Among the Reptiles of cold and temperate countries, this torpid state uniformly occupies a considerable part of the year; as it does also with Insects, terrestrial Mollusks, and other Invertebrated animals, which are subject to the influence of the cold. On the other hand, Fishes, Crustacea, and other marine animals, do not usually appear to pass into a state of torpidity; the temperature of the medium they inhabit never undergoing a degree of depression nearly so great as that of the atmosphere. The amount of change necessary to produce this effect, or on the other hand to call the animals from a state of torpidity to one of active energy, differs for different species; and there is probably a considerable difference even among individuals of the same species, according to the temperature under which they habitually live. Thus one animal may remain torpid under a degree of warmth which will be sufficient to arouse another of the same kind accustomed to a somewhat colder climate; because the stimulus is *relatively* greater to the latter.

129. It was observed by Mr. Darwin, that at Bahia Blanca, in South America, the first appearance of activity in animal and vegetable life, a few days before the vernal equinox, presented itself under a mean temperature of 58°, the range of the thermometer in the middle of the day being between 60° and 70°. The plains were ornamented by the flowers of a pink wood-sorrel, wild peas, evening primroses, and geraniums; the birds began to lay their eggs, numer-

ous beetles were crawling about; and lizards, the constant inhabitants of a sandy soil, were darting about in every direction. Yet a few days previously, it seemed as if nature had scarcely granted a living creature to this dry and arid country; and it was only by digging in the ground that their existence had been discovered,—several insects, large spiders, and lizards, having been found in a half torpid state. Now at Monte Video, four degrees nearer the Equator, the mean temperature had been above 58° for some time previously, and the thermometer rose occasionally during the middle of the day, to 69° or 70°; yet with this elevated temperature, almost equivalent to the full summer heat of our own country, almost every beetle, several genera of spiders, snails, and land-shells, toads and lizards, were still lying torpid beneath stones. We have seen that at Bahia Blanca, whose climate is but a little colder, this same temperature, with a rather less extreme heat, was sufficient to awake all orders of animated beings;—showing how nicely the required degree of stimulus is adapted to the general climate of the place, and how little it depends on absolute temperature.

130. We may learn much from the Geographical distribution of the different species of cold-blooded animals, in regard to the influence of temperature on Animal life. No general inferences of this kind can be founded upon the distribution of warm-blooded animals; since their own heat-evolving powers make them in great degree independent of external warmth. And it is probably from the distribution of the marine tribes, whose extension is less influenced by local peculiarities, that the most satisfactory deductions are to be drawn. In regard to the class of Crustacea, which is the one that has been most fully investigated in this respect, the following principles have been pointed out by M. Milne Edwards; and they are probably more or less applicable to most others.

I. *The varieties of form and organization manifest themselves more, in proportion as we pass from the Polar Seas towards the Equator.*—Thus on the coast of Norway, where there is frequently a vast multiplication of *individuals* of the same species, the number of *species* is very small; but the latter increases rapidly as we go southwards. Thus the number of species of Crustacea of the two highest Orders, known to exist on the coast of Norway and in the neighbouring seas, is only 16; but 82 are known to be the inhabitants of the western shores of Britain, France, Spain, and Portugal; 114 are known in the Mediterranean Sea; and 202 in the Indian Ocean. A similar increase may be observed in following the coast of the New World, from Greenland to the Caribbean Sea.

II. *The differences of form and organization are not only more numerous and more characteristic in the warm than in the cold regions of the globe; they are also more important.*—The number of natural groups, which we find represented in the polar and temperate regions, is much smaller than that, of which we find types or examples in the tropical seas. In fact, nearly all the principal forms which

are met with in colder regions, also present themselves in warm; but a very large proportion of the latter have no representatives among the former. Of the three *primary* groups composing the Class, indeed, one is altogether wanting beyond the 44th degree of latitude; and in the other two there are whole Orders, as well as numerous subordinate divisions, which are as completely restricted to the warmer seas.

III. *Not only are those Crustacea, which are most elevated in the scale, deficient in the Polar regions; but their relative number increases rapidly as we pass from the Pole towards the Equator.*—Thus the Brachyoura,* which must be considered as the most elevated of the whole series, are totally absent in some parts of the arctic region; and we find their place taken by the far less complete Edriophthalma, with a small number of Anomourous and Macrourous Decapods. In the Mediterranean, however, the Decapods surpass the Edriophthalma in regard to the number of species; and the Brachyourous division of the former predominates over the Macrourous, in the proportion of two to one. And in the East and West Indies, the species of Brachyoura are to those of Macroura, as three, four, or even five, to one. Again, the *Land Crabs*, which are probably to be regarded as taking the highest rank among the Brachyoura (and therefore in the entire class), are only to be met with between the tropics. Moreover, of the *fluviatile* Decapods (inhabiting rivers, brooks, and fresh-water lakes,) a large proportion belong, in tropical regions, to the elevated type of the Brachyoura; whilst all those found in the temperate and arctic zones (the River Cray-fish and its allies) belong to the Macrourous division.

IV. When we compare together the Crustacea of different parts of the world, we observe that *the average size of these animals is considerably greater in tropical regions, than in the temperate or frigid climes.*—The largest species of the arctic and antarctic seas are far smaller than those of the tropical ocean; and they bear a much smaller proportion to the whole number. Further, in almost every natural group, we find that the largest species belong to the equatorial regions; and that those which represent them (or take their place, as it were,) in temperate regions, are of smaller dimensions.

V. It is where the species are most numerous and varied, and where they attain the greatest size, in other words, *where the temperature is most elevated,—that the peculiarities of structure which characterize the several groups are most strongly manifested.* Thus the transverse development of the cephalo-thorax, which is so remarkable in the Brachyourous Decapods (the *breadth* of the carapace or arched shell in the typical Crabs being much greater than its *length* from back to front), is carried to its greatest extent in certain Crustacea of the Equatorial re-

* The Decapoda or ten-footed Crustaceans constitute the highest or most perfectly organized Order of the class. This Order is composed of the *Brachyoura* (short-tailed) or Crabs; of the *Macroura* (long-tailed) or Lobsters, Shrimps, &c.; and of the *Anomoura* (dissimilar-tailed) or Hermit-Crabs, &c.

gion; and the same might be said of the characteristic peculiarities of most other natural groups. Further, it is in this region that we find the greatest number of those anomalous forms, which depart most widely from the general structure of the Class.

VI. Lastly, *there is a remarkable coincidence between the temperature of different regions, and the prevalence of certain forms of Crustacea.*—Thus there are few *genera* to be met with in the West Indian seas which have not their representatives in the East Indian,—the species, however, being usually different. The same may be said of the genera inhabiting the temperate regions of the globe;—similar *generic* forms being usually met with in the corresponding parts of the Old and New World, and of the Northern and Southern Hemispheres, although the species are almost invariably different.

131. Now although, as appears from the foregoing general statements, the number of *species* of Crustacea inhabiting the colder seas bears a very small proportion to that which is found within the tropics, and although the species formed to inhabit cold climates are so far inferior, both as to size and as to perfection of development, yet it does not follow that the same proportion exists in regard to the relative amount of Crustacean life in the two regions: for this depends upon the multiplication of *individuals*. In fact it may be questioned whether there is any inferiority in this respect; so abundant are some of the smaller species in the Arctic and Antarctic, as well as in the Temperate seas. Thus we see that a low range of temperature is as well adapted to sustain *their* life, as a higher range is to call forth those larger and more fully developed forms, which abound in the tropical ocean. This is an obvious reason why the *seas* of the frigid zones should be much more abundantly peopled than the *land;* the mean temperature of the former being much higher. And it would almost seem as if Nature had intended to compensate for the dreariness and desolation of the one, by the profuseness of life which she has fitted the other to support.

132. The influence of Temperature in modifying the size of individual Animals of the same species, is not so strongly marked as it is in the case of Plants; for this reason, perhaps, that an amount of continued depression or elevation, which might be sustained by a Plant, but which would exert a modifying influence upon its growth, would be fatal to an animal formed to exist in the same climate. Instances are not wanting, however, in which such a modifying influence is evident; and these, as might be anticipated, are to be met with chiefly among the cold-blooded tribes. Thus the *Bulimus rosaceus*, a terrestrial Mollusk, is found on the mountains of Chili of so much less a size than that which it attains on the coast, as to have been described as a distinct species. And the *Littorina petræa*, found on the *south* side of Plymouth Breakwater, acquires, from its superior exposure to light and heat (though, perhaps, also from the greater supply of nutriment which it obtains), twice the size common to individuals living on the north side within the harbour. The following circumstance shows the

favourable influence of an elevated temperature, in producing an unusual prolificness in Fish; which must be connected with general vital activity. Three pairs of Gold-fish were placed, some years since, in one of the engine-dams or ponds common in the manufacturing districts, into which the water from the engine is conveyed for the purpose of being cooled; the average temperature of such dams is about 80°. At the end of three years the progeny of these Fish, which were accidentally poisoned by verdigris mixed with the refuse tallow from the engine, were taken out by wheelbarrows-full. It is not improbable that the unusual supply of aliment, furnished by the refuse grease that floats upon these ponds (which would impede the cooling of the water, if it were not consumed by the Fish), contributed with the high temperature to this unusual fecundity.

133. The influence of variations in the Heat of the body upon its vital activity, is further manifested by the very remarkable experiments of Dr. Edwards, who has shown that cold-blooded animals *live much faster* (so to speak) at *high* temperatures than at low; so that they die much sooner when deprived of other vital stimuli. Thus when Frogs were confined in a limited quantity of water, and were not permitted to come to the surface to breathe, it was found that the duration of their lives was inversely proportioned to the degree of heat of the fluid. Thus when it was cooled down to the freezing point, the frogs immersed in it lived during from 367 to 498 minutes. At the temperature of 50°, the duration of their lives was from 350 to 375 minutes; at 72°, it was from 90 to 35 minutes; at 90°, from 12 to 32 minutes; and at 108°, death was almost instantaneous. The prolongation of life at the lower temperatures was not due to torpidity, for the animals perform the functions of voluntary motion, and enjoy the use of their senses; but it is occasioned by their diminished activity, which occasions a less demand for air. On the other hand, the elevation of temperature increases the demand for air, and causes speedier death when it is withheld, by increasing the general agility. The natural habits of these animals are in correspondence with these facts. During the winter, the influence of a sufficient amount of aërated water upon their exterior serves to maintain the required amount of respiration through the skin, so that they are not obliged to come to the surface to take in air by the mouth. As the season advances, however, their activity increases, a larger amount of respiration is required, and the animals are obliged to come frequently to the surface to breathe. During summer the yet higher temperature calls forth an increased energy and activity in all the vital functions; the respiration must be proportionably increased; the action of the air upon the cutaneous surface, as well as upon the lungs, is required; and if the animals are prevented from quitting the water to obtain this, they die as soon as the warmth of the season becomes considerable.

134. The result of experiments on Fishes, in regard to the deprivation or limited supply of the air contained in the water in which they are immersed, is exactly similar; the duration of life being in-

versely as the temperature. And precisely the same has been ascertained with respect to hybernating Mammals; which, as already remarked, are for a time reduced, in all such conditions, to the level of cold-blooded animals.

135. Conformably to the same principle, we find that cold-blooded animals are enabled to sustain the deprivation of food during a much longer period, at cold temperatures, than at warm. The case is precisely the reverse in regard to most warm-blooded animals; since in *them* a due supply of food is a condition absolutely necessary (as we have already seen) for the maintenance of that amount of bodily heat, whose loss is fatal to them; and exposure to a low temperature will of course more speedily bring about that crisis. Hence it is that Cold and Starvation combined are so destructive to life. But in this respect, also, the hybernating Mammals correspond with the cold-blooded classes; their power of abstinence being inversely as the temperature of their bodies.

136. Although a very low temperature is positively inconsistent with the continuance of vital *activity*, in Animals as in Plants, yet we find that even very severe cold is not necessarily destructive of the vital *properties* of organized tissues; so that, on a restoration of the proper amount of heat, their functions may continue as before. Of this we have already noticed an example, in the case of frost-bitten limbs; but the fact is much more remarkable, when considered in reference to the whole body of an animal, and the complete suspension of all its functions. Yet it is unquestionably true, not only of the lowest and simplest members of the Animal kingdom, but also of Fishes and Reptiles. In one of Captain Ross's Arctic Voyages, several Caterpillars of the *Laria Rossii* having been exposed to a temperature of 40° *below zero*, froze so completely, that, when thrown into a tumbler, they chinked like lumps of ice. When thawed, they resumed their movements, took food, and underwent their transformation into the Chrysalis state. One of them, which had been frozen and thawed four times, subsequently became a Moth. The eggs of the Slug have been exposed to a similar degree of cold, without the loss of their fertility. It is not uncommon to meet, in the ice of rivers, lakes, and seas, with Fishes which have been completely frozen, so as to become quite brittle; and which yet revive when thawed. The same thing has been observed in regard to Frogs, Newts, &c.; and the experiment of freezing and subsequently thawing them, has been frequently put in practice. Spallanzani kept Frogs and Snakes in an ice-house for three years; at the end of which period they revived on being subjected to warmth.

137. It does not appear, however, that the same capability exists, in regard to any warm-blooded animals; since if a *total* suspension* of vital activity take place in the body of a Bird or Mammal for any

* In the case of hybernating Mammals, the suspension is not total; and if it be rendered such, the same result follows as in other instances.

length of time, in consequence of the prolonged application of severe cold, recovery is found to be impossible. The power which exists in these animals, however, of generating a large amount of heat within their bodies, acts as a compensation for the want of the faculty possessed by the cold-blooded tribes ; since they can resist for a great length of time (if in their healthy or normal condition) the depressing influence of a temperature sufficiently low to produce a complete suspension in the activity of the latter.

138. It only remains to say a few words regarding the degree of *heat* which certain Animals can sustain without prejudice, and which even appears to be genial to them. Among the higher classes, this range *seems* to be capable of great extension. Thus many instances are on record of a heat of from 250° to 280° being endured, in dry air, for a considerable length of time, without much inconvenience ; and persons who have become habituated to this kind of exposure can (with proper precautions) sustain a temperature of from 350° to 500°. In all such cases, however, the real heat of the body undergoes very little elevation ; for, by means of the copious evaporation from its surface, the external heat is prevented from acting upon it. But if this evaporation be prevented, either by an insufficiency in the supply of fluid from within, or by the saturation of the surrounding air with moisture, the temperature of the body begins to rise ; and it is then found, that it cannot undergo an elevation of more than a few degrees, without fatal consequences. Thus in several experiments which have been tried on different species of warm-blooded animals, for the purpose of ascertaining the highest temperature to which the body could be raised without the destruction of life, it was found that as soon as the heat of the body had been increased, by continued immersion in a limited quantity of hot air (which would soon become charged with moisture), to from 9°—13° above the natural standard, the animals died. In general, Mammals die, when the temperature of their bodies is raised to about 111°; the heat which is natural to the bodies of Birds. The latter are killed by an equal amount of elevation of bodily heat above *their* natural standard.

139. Hence we see that the actual range of temperature, within which vital activity can be maintained in warm-blooded animals, is extremely limited ; a temporary elevation of the bodily heat to 13° above the natural standard, or a depression to 30° below it, being positively inconsistent, not merely with the continuance of vital operations, but also with the preservation of vital properties ; and a continued departure from that standard, to the extent of only a very few degrees above or below it, being very injurious. The provisions with which these animals are endowed, for generating *heat* in their interior, so as to supply the external deficiency, and for generating *cold* (so to speak), when the external temperature is too high, are therefore in no respect superfluous : but are positively necessary for the maintenance of the life of such animals, in any climate, save one whose *mean* should be conformable to their standard, and whose

extremes should never vary more than a very few degrees above or below it. Such a climate does not exist on the surface of the earth.

140. The range of *external* temperature, within which cold-blooded animals can sustain their activity, is much more limited, as well in regard to its highest as to its lowest point; notwithstanding that the range of *bodily* heat, which is consistent with the maintenance of their life, is so much greater. In those which, like the Frog, have a soft moist skin, which permits a copious evaporation from the surface, a considerable amount of heat may be resisted, provided the air be dry, and the supply of fluid from within be maintained.* But immersion in water of the temperature of 108°, is almost immediately fatal. In many other cold-blooded animals, elevation of the temperature induces a state of torpidity, analogous to that which is produced by its depression. Thus the *Helix pomatia* (Edible Snail) has been found to become torpid and motionless in water at 112°; but to recover its energy when placed in a colder situation. It would seem to be partly from this cause, but partly also from the deprivation of moisture, that the *hottest* part of the tropical year brings about a cessation of activity in many tribes of cold-blooded animals, as complete as that which takes place during the *winter* of temperate climates.

141. The highest limit of temperature compatible with the life of Fishes has not been certainly ascertained: and it appears probable that there are considerable variations in this respect amongst different species. Thus it is certain that there are some which are killed by immersion in water at 104°; whilst it is also certain that others can not only exist, but can find a congenial habitation, in water of 113°, or even of 120°; and examples of the existence of Fishes in thermal springs of a much higher temperature than this, have been put on record. Various fresh water Mollusca have been found in thermal springs, the heat of which is from 100° to 145°. Rotifera and other animalcules have been met with in water at 112°. Larvæ of Tipulæ have been found in hot springs of 205°; and small black beetles, which died when placed in cold water, in the hot sulphur baths of Albano. Entozoa inhabiting the bodies of Mammalia and of Birds must of course be adapted to a constant temperature of from 98° to 110°; and they become torpid when exposed to a cool atmosphere. These lowly organized animals seem more capable of resisting the effects of extreme heat, than any others;—at least if we are to credit the statement, that the Entozoa inhabiting the intestines of the Carp have been found alive, when the Fish was brought to table after being boiled.—In all such cases, it is to be remembered, the heat of the animal body must correspond with that of the fluid in which it is

* The Frog has a remarkable provision for this purpose; in a bladder, which is *structurally* analogous to our Urinary bladder, but which has for its chief function to contain a store of fluids for the exhaling process. It has been noticed that, when this store is exhausted by continued exposure of the animal to a warm dry atmosphere, the bladder becomes full again, when the animal is placed in a moist situation, even though it take in no liquid by its mouth.

immersed; and we have here, therefore, evident proof of the compatibility of vital activity, in certain cases, with a very elevated temperature. Additional and more exact observations, however, are much wanting on this subject.

3. *On Electricity, as a Condition of Vital Action.*

142. Much less is certainly known with respect to the ordinary influence of this agent, than in regard to either of the two preceding; and yet there can be little doubt, from the effects we observe when it is powerfully applied, as well as from our knowledge of its connection with all Chemical phenomena, that it is in constant though imperceptible operation. Electricity differs from both Light and Heat in this respect;—that no manifestation of it takes place so long as it is uniformly diffused, or is in a state of *equilibrium;* but in proportion as this equilibrium is disturbed, by a change in the electric condition of one body, which is prevented, by its partial or complete insulation, from communicating itself to others, in that proportion is a *force* produced, which exerts itself in various ways according to its degree. The *mechanical* effects of a powerful charge, when passed through a substance that is a bad conductor of Electricity, are well known; on the other hand, the *chemical* effects of even the feeblest current are equally obvious. The agency of Electricity in producing Chemical change is the more powerful, in proportion as there is already a predisposition to that change; thus, as already remarked, the largest collection of oxygen and hydrogen gases, or of hydrogen and chlorine, mingled together, may be caused to unite by the minutest electric spark, which gives the required *stimulus* to the mutual affinities that were previously dormant. Hence it cannot but be inferred, that its agency in the Chemical phenomena of living bodies must be of an important character; but this may probably be exerted rather in the way of aiding decomposition, than of producing new combinations, to which (as we have seen) Light appears to be the most effectual stimulus. Thus it has been shown that pieces of meat, that have been electrified for some hours, pass much more rapidly into decomposition, than similar pieces placed under the same circumstances, but not electrified. And in like manner, the bodies of animals that have been killed by electric shocks, have been observed to putrify much more readily than those of similar animals killed by injury to the brain. It is well known, moreover, that in thundery weather, in which the electric state of the atmosphere is much disturbed, various fluids containing organic compounds, such as milk, broth, &c., are peculiarly disposed to turn sour; and that saccharine fluids, such as the wort of brewers, are extremely apt to pass into the acetous fermentation.

143. The actual amount of influence, however, which Electricity exerts over a growing Plant or Animal, can scarcely be estimated. It would, perhaps, be the most correct to say, that the state of Elec-

tric *equilibrium* is that which is generally most favourable; and we find that there is a provision in the structure of most living beings, for maintaining such an equilibrium,—not only between the different parts of their own bodies, but also between their own fabrics and the surrounding medium. Thus a charge given to any part of a Plant or Animal, is immediately diffused through its whole mass; and though Organized bodies are not sufficiently good conductors to transmit very powerful shocks without being themselves affected, yet a discharge of any moderate quantity may be effected through them, without any permanent injury,—and this more especially if it be made to take place slowly. Now the points on the surfaces of Plants appear particularly adapted to effect this transmission; thus it has been found that a Leyden jar might be discharged by holding a blade of grass near it, in one-third of the time required to produce the same effect by means of a metallic point; and an Electroscope furnished with Vegetable points has been found to give more delicate indications of the electric state of the atmosphere, than any other. Plants designed for a rapid growth have generally a strong pubescence or downy covering; and it does not seem improbable that one purpose of this may be, to maintain that equilibrium between themselves and the atmosphere, which would otherwise be disturbed by the various operations of vegetation, and especially by the process of evaporation, which takes place with such activity from the surface of the leaves.

144. There appears to be sufficient evidence that, during a highly electrical state of the atmosphere, the growth of the young shoots of certain plants is increased in rapidity; but it would be wrong thence to infer that this excitement is useful to the process of Vegetation in general, or that the same kind of electric excitement universally operates to the benefit or injury of the Plant. From some experiments recently made it would appear, that potatoes, mustard and cress, cinerarias, fuchsias, and other plants, have their development, and, in some instances, their productiveness, increased by being made to grow between a copper and a zinc plate, connected by a conducting wire; while, on the other hand, geraniums and balsams are destroyed by the same influence. The transmission of a series of moderate sparks through plants, in like manner, has been found to accelerate the growth of some, and to be evidently injurious to others. It is not unreasonable to suppose, that, as a great variety of chemical processes are constantly taking place in the growing plant, an electric disturbance, which acts as a stimulus to some, may positively retard others; and that its good or evil results may thus depend upon the balance between these individual effects. This would seem the more likely from the circumstance, that, in the process of Germination, the chemical changes concerned in which are of a simpler character, Electricity seems to have a more decided and uniform influence. The conversion of the starch of the seed into sugar, which is an essential part of this change, involves the liberation of a large quantity of carbonic, and of some acetic acid. Now as all acids are negative, and

as like electricities repel each other, it may be inferred that the seed is at that time in an electro-negative condition; and it is accordingly found that the process of germination may be quickened, by connection of the seed with the negative pole of a feeble galvanic apparatus, whilst it is retarded by a similar connection with the positive pole. A similar acceleration may be produced by the contact of feeble alkaline solutions, which favour the liberation of the acids; whilst, on the same principle, a very small admixture of acid in the fluid with which the seed is moistened, is found to produce a decided retardation.

145. It is well known that Trees and Plants may be easily killed by powerful electric shocks; and that, when the charge is strong enough (as in the case of a stroke of lightning), violent mechanical effects,—as the rending of trunks, or even the splitting and scattering of minute fragments,—are produced by it. But it has also been ascertained, that charges which produce no perceptible influence of this kind, may destroy the life of Plants; though the effect is not always immediate. In particular it has been noticed, that slips and grafts are prevented from taking root and budding. There can be little doubt that, in these instances, a change is effected in the chemical state of the solids or fluids; although no structural alteration is perceptible.

146. In regard to the influence of Electricity upon the Organic functions of Animals, still less is certainly known; but there is evidence that it may act as a powerful stimulant in certain disordered states of them. Thus in Amenorrhea, a series of slight but rapidly-repeated electric shocks will often bring on the catamenial flow; and it is certain that chronic tumours have been dispersed, and dropsies relieved by the excitement of the absorbent process, through similar agency. Again, it is indubitable that a highly electric state of the atmosphere produces very marked effects on the general state of many individuals; and brings on in some a degree of languor and depression, which cannot be accounted for in any other way. An instance is on record, in which the atmosphere was in such an extraordinary state of electric disturbance, that all pointed bodies within its influence exhibited a distinct luminosity; and it was noticed, that all the persons who were exposed to the agency of this highly electrified air, experienced spasms in the limbs and an extreme state of lassitude.

147. Animals, like Plants, are liable to be killed by shocks of Electricity; even when these are not sufficiently powerful to occasion any *obvious* physical change in their structure. But, as formerly mentioned (§ 69) there can be no doubt that minute changes may be produced in their delicate parts, which are quite sufficient to account for the destruction of their vitality, even though these can only be discerned with the Microscope. The production of changes in the Chemical arrangement of their elements, is, however, a much more palpable cause of death; since it may be fully anticipated beforehand, and can easily be rendered evident. To take one instance only;—

it is well known, that *albumen* is made to coagulate, *i. e.*, is changed from its soluble to its insoluble form, under the influence of an electric current; and it cannot be doubted that the production of this change in the fluids of the living body (almost every one of which contains albumen), even to a very limited extent, is quite a sufficient cause of death, even in animals that are otherwise most tenacious of life. "I once discharged a battery of considerable size," says Dr. Hodgkin, "through a common Earth-worm, which would in all probability have shown signs of life long after minute division. Its death was as sudden as the shock; and the semi-transparent substance of the animal was changed like Albumen which has been exposed to heat."

148. Electricity possesses, in a remarkable degree, the power of exciting the Contractility of Muscular fibre; but this series of phenomena will be more fitly described, when the properties of that tissue are under consideration.

4. *Of Moisture, as a Condition of Vital Action.*

149. Independently of the utility of Water as an article of *food*, and of the part it performs in the Chemical operations of the living body, by supplying two of their most important materials (oxygen and hydrogen), there can be no doubt that a certain supply of moisture is requisite, as one of the conditions without which no vital actions can go on. It has been already remarked, indeed, that one of the distinguishing peculiarities of organized structures, is the presence in all of them of solid and fluid component parts; and this in the minutest portions of the organism, as well as in the aggregate mass. And in all the *vital*, as well as in the *chemical* actions, to which these structures are subservient, the presence of fluid is essential. All nutrient materials must be reduced to the fluid form, before they can be assimilated by the solids; and, again, the solid matters which are destined to be carried off by excretion, must be again reduced to the liquid state, before they can be thus withdrawn from the body. The tissues in which the most active changes of a purely vital character are performed,—namely, the Nervous and Muscular,—naturally contain a very large proportion of water; the former as much as 80, and the latter 77, per cent. On the other hand, in tissues whose function is of a purely mechanical nature, such as Bone, the amount of fluid is as small as is consistent with the maintenance of a certain amount of nutrient action in its interior. By the long-continued application of dry heat to a dead body, its weight was found to be reduced from 120 pounds to no more than 12; so that, taking the average of the whole, the amount of water, not chemically combined, but simply interstitial, might be reckoned at as much as 90 per cent. It is certain, however, that much decomposition and loss of solid matter must have taken place in this procedure; and we shall probably estimate the proportion more accurately, if we regard the weight of the fluids

of the human body as exceeding that of the solids by six or seven times.

150. There is a great variation in this respect, however, among different tribes of living beings. There are probably no highly-organized Animals, whose texture contains *less* fluid than that of Vertebrata (unless, it may be, certain Beetles); but there can be no question that, among some of the Zoophytes, the proportion of solids to fluids is just the other way. In those massive coral-forming animals, which seem to have been expressly created for the purpose of building up islands and even continents from the depths of the ocean, we find the soft tissues confined to the surface, and all within of a rocky hardness. It is not, however, correct to say (as is commonly done), that the coral-polypes build up these stony structures as habitations for themselves; for the stony matter is deposited, by an act of nutrition, in the living tissue of these animals, just as much as it is in the bones of Man. But the parts once consolidated henceforth remain dead, so far as the animal is concerned; they are not connected with the living tissues by any vessels, nerves, &c.; their density prevents them from undergoing any but a very slow disintegrating change, so that they require and receive no nutrient materials; and they might be altogether removed, by accident or decay, without any direct injury to the still active, because yet unconsolidated, portions of the polype-structure.

151. There is a close correspondence, in this respect, between the condition of the stony or horny stem of a Coral, and the heart-wood of the trunk of a Tree; for the latter, becoming consolidated by internal deposit, for the purpose of affording mechanical support, is thenceforth totally unconnected with the vegetative operations of the tree, and might be removed (as it frequently is by natural decay) without affecting them. In all the parts, in which the nutrient processes are actively going on, do we observe that the tissue contains a large proportion of water; and that, if the succulent portions be dried up, their vital properties are destroyed. Thus it is in the soft tissue at the extremities of the radicles or root fibres, that the function of absorption takes place with the greatest activity; so that these parts have received the name of *spongioles:* it is in the cells which form the soft parenchyma of the leaves, that the elaboration of the sap takes place, the fixation of carbon from the atmosphere, and the preparation of the peculiar secretions of the plant: and it is in the space between the bark and the wood, which is occupied (at the season of most active growth) by a saccharine glutinous fluid, that the formation of the new layers of wood and bark takes place. Now, as soon as these parts become consolidated, they cease to perform any active vital operations. The spongioles, by the lengthening of the root-fibres, become converted into a portion of those fibres, and remain subservient merely to the transmission of the fluids absorbed; the leaves gradually become choked by the saline and earthy particles contained in the ascending sap, which they have had no power of

excreting, and they wither, die, and fall off; and the new layers of wood and bark, when once formed, undergo but little further change, and are subservient to little else than the transmission of the ascending and descending sap to the parts where they are to be respectively appropriated.

152. There are some remarkable instances in both the Animal and Vegetable kingdoms, of an immense preponderance in the amount of the fluids over that of the solids of the structure. This is characteristic of the whole class of *Acalephæ* or *Jelly-Fish*, giving to their tissues that softness from which their common name is derived; these animals, in consequence, are unable to live out of water; for, when they are removed from it, a drain of their fluids commences, which soon reduces their weight to a degree that destroys their lives,—a *Medusa* weighing fifty pounds being thus dried down to a weight of as many grains. The most remarkable instances of a parallel kind among Plants, are to be found in the tribe of Fungi; certain members of which are distinguished by an almost equally small proportion of solid materials in their textures, presenting a most delicate gossamer-like appearance to the eye, and possessing such little durability, that they come to maturity and undergo decay in the course of a few hours. These are not inhabitants of the water, but will vegetate only in a very damp atmosphere.

153. As we find various Plants and Animals very differently constructed in regard to the amount of fluid contained in their tissues, so do we also find them dependent in very different degrees upon a constant supply of external moisture. There is no relation, however, between the succulence of a plant, and the degree of its dependence upon water; in fact, we commonly find the most succulent plants growing in the driest situations; whilst the plants, which are adapted to localities where they can obtain a constant supply of fluid, are not usually remarkable for the amount of water in their own structure. This, however, is easily explained. We find the most succulent plants,—such as the *Sedums* or Stone-crops of our own country, and the *Cacti* and *Euphorbiæ* of the tropics,—in dry exposed situations, where they seem as if they would be utterly destitute of nutriment. The fact is, however, that they lose their fluid by exhalation very slowly, in consequence of their small number of stomata; whilst, on the other hand, they absorb with great readiness during rainy weather, and are enabled, by the fleshiness of their substance, to store up a large quantity of moisture until it is required. In some parts of Mexico, the heat is so intense, and the soil and atmosphere so dry, during a large part of the year, that no vegetation is found at certain seasons, save a species of Cactus; this affords a wholesome and refreshing article of food, on which travelers have been able to subsist for many days together, and without which these tracts would form impassable barriers. On the other hand, the plants of damp situations usually exhale moisture almost as fast as they imbibe it; and consequently, if their usual supply be cut off or diminished, they

soon wither and die. Plants that usually live entirely submerged, are destitute of the cuticle or thin skin, which covers the surface in other cases; in consequence of this, they very rapidly lose their fluid, when they are removed from the water; and they are hence dependent upon constant immersion in it for the continuance of their lives, although their tissues may not be remarkable for the amount of fluid which they contain.

154. There are some Plants which are capable of adapting themselves to a great variety of situations, differing widely as to the amount of moisture which their inhabitants can derive from the soil and atmosphere; and we may generally notice a marked difference in the mode of growth, when we compare individuals that have grown under opposite circumstances. Thus a plant from a dry exposed situation, shall be stunted and hairy, whilst another, of the same species, but developed in a damp sheltered situation, shall be rank and glabrous (smooth). But in general there is a certain quantity of moisture congenial to each species; and the excess or deficiency of this condition has, in consequence, as great an influence in determining the geographical distribution of Plants, as the amount of light and heat. Thus, as already remarked, the Orchideæ and Tree Ferns of the tropics grow best in an atmosphere loaded with dampness; whilst the Cactus tribe, for the most part, flourishes best in dry situations. The former become stunted and inactive, if limited in their supply of aërial moisture; whilst the latter, if too copiously nourished, become dropsical and liable to rot. Among the plants of our own country, we find a similar limitation; a moist boggy situation being indispensable to the growth of some, whilst a dry exposed elevation is equally essential to the healthy development of others. There is a beautiful species of exotic Fern, the *Trichomanes speciosum;* the rearing of which has been frequently attempted in this country and elsewhere, without success; but which only requires an atmosphere saturated with dampness, for its healthy development, being easily reared in one of Mr. Ward's closed glass cases. In this, as in similar examples, it is only necessary to imitate as closely as possible the conditions under which the species naturally grows; and sometimes this can only be accomplished, by surrounding the plant with small trees and shrubs, so as to give it a moister atmosphere than it could otherwise attain. Professor Royle mentions the growth, under such circumstances, of a fine specimen of the *Xanthochymus dulcis*, one of the *Guttiferæ* or Gamboge-trees, in the garden of the King of Delhi; this tree is naturally found only in the southern parts of India; and the success of its cultivation in this northerly situation is entirely due to its being sheltered by the numerous buildings within the lofty palace wall, surrounded by almost a forest of trees, and receiving the benefit of perpetual irrigation from a branch of the canal which flows through the garden.

155. In regard to the influence of external moisture upon Animal life, there is much less to be said; since the mode in which fluid is

received into the system is so entirely different. It may be remarked, however, that Animals habitually living beneath the water, like submerged Plants, are usually incapable of sustaining life for any length of time when removed from it, in consequence of the rapid loss of fluid which they undergo from their surface. It is, however, by the desiccation of the *respiratory* surface, preventing the due aëration of the blood, that the fatal result is for the most part occasioned; since we find that when there is a special provision to prevent this, as in the case of certain Fishes and Crustacea, the animals can quit the water for a great length of time. There can be no doubt that the amount of Atmospheric moisture is one of those conditions, which are collectively termed Climate, and which influence the geographical distribution of Animals, no less than that of Plants. But it is difficult to say how far the variations in moisture act alone. There can be no doubt, however, of their operation; for every one is conscious of the effect, upon his health and spirits, of such variations as take place in the climate he may inhabit. The two principal modes in which these will operate, will be by accelerating or checking the exhalation of fluid from the skin and from the pulmonary surface; for when the air is already loaded with dampness, the exhaled moisture cannot be carried off with the same readiness as when it is in a condition of greater dryness; and it will consequently either remain within the system, or it will accumulate and form sensible perspiration.

156. Now each of these states may be salutary, being the one best adapted to particular constitutions, or to different states of the same individual. A cold drying wind shall be felt as invigorating to the relaxed frame, as it is chilling to one that has no warmth or moisture to spare; on the other hand, a warm damp atmosphere, which is refreshing to the latter, shall be most depressing to the former. All who have tried the effect of closely-fitting garments, impervious to moisture, are well aware how oppressive they soon become; this feeling being dependent upon the obstruction they occasion to the act of perspiration, by causing the included air to be speedily saturated with moisture. When the fluids of the system have been diminished in amount, either by the suspension of a due supply of water, or by an increase in the excretions, there is a peculiar refreshment in a soft damp atmosphere, or in a warm bath, which allows the loss to be replaced by absorption through the general cutaneous surface. The reality of such absorption has been placed beyond all doubt, by observations upon men, who had been exposed to a hot dry air for some time, and afterwards placed in a warm bath; for it was found that the system would by this unusual means supply the deficiency, which had been created by the previous increase in the transpiration.

157. The effect of a moist or dry atmosphere, then, upon the Animal body, cannot be by any means unimportant; although, as we shall hereafter see, there exists in it a series of the most remarkable

provisions for regulating the amount of its fluids. The influence of atmospheric moisture, however, is most obvious in disordered states of the system. Thus in persons who are subject to the form of Dyspepsia called atonic, which is usually connected with a generally-relaxed condition of the system, a very perceptible influence is experienced from changes in the quantity of atmospheric moisture; the digestive power, as well as the general functions of the body, being invigorated by dryness, and depressed by damp. Again, there is no doubt that, where a predisposition exists to the Tuberculous Cachexia, it is greatly favoured by habitual exposure to a damp atmosphere, especially when accompanied by cold; indeed it would appear, from the influence of cold damp situations upon animals brought from warmer climates, that these two causes may induce the disease, in individuals previously healthy. On the other hand, there are some forms of pulmonary complaints, in which an irritable state of the mucous membrane of the bronchial tubes has a large share; when this irritation presents itself in the *dry* form, a warm moist atmosphere is found most soothing to it; whilst a drier and more bracing air is much more beneficial, when the irritation is accompanied by a too copious secretion.

158. Although, as already stated, no vital actions can go on without a reaction between the *solids* and *fluids* of the body, yet there may be an entire loss of the latter, in certain cases, without necessarily destroying life; the structure being reduced to a state of dormant vitality, in which it may remain unchanged for an unlimited period; and yet being capable of renewing all its actions, when moisture is again supplied. Of this we find numerous examples among both the Vegetable and the Animal kingdoms. Thus the Mosses and Liverworts, which inhabit situations where they are liable to occasional drought, do not suffer from being, to all appearance, completely dried up; but revive and vegetate actively, as soon as they have been thoroughly moistened. Instances are recorded, in which Mosses that have been for many years dried up in a Herbarium, have been restored by moisture to active life. There is a *lycopodium* (Club-Moss) inhabiting Peru, which, when dried up for want of moisture, folds its leaves and contracts into a ball; and in this state, apparently quite devoid of animation, it is blown hither and thither along the surface by the wind. As soon, however, as it reaches a moist situation, it sends down its roots into the soil, and unfolds to the atmosphere its leaves, which, from a dingy brown, speedily change to the bright green of active vegetation. The *Anastatica* (Rose of Jericho) is the subject of similar transformations; contracting into a ball, when dried up by the burning sun and parching air; being detached by the wind from the spot where its slender roots had fixed it, and rolled over the plains to indefinite distances; and then, when exposed to moisture, unfolding its leaves, and opening its rose-like flower, as if roused from sleep. There is a blue Water-Lily, abounding in several of the canals at Alexandria, which at certain seasons become so dry, that

their beds are burnt as hard as bricks by the action of the sun, so as to be fit for use as carriage roads; yet the plants do not thereby lose their vitality; for when the water is again admitted, they resume their growth with redoubled vigour.

159. Among the lower Animals, we find several of considerable complexity of structure, which are able to sustain the most complete desiccation. This is most remarkably the case in the common *Wheel-Animalcule;* which may be reduced to a state of most complete dryness, and kept in this condition for any length of time, and which will yet revive immediately on being moistened. The same individuals may be treated in this manner, over and over again. Experiments have been carried still further with the allied tribe of *Tardigrades;* individuals of which have been kept in a vacuum for thirty days, with sulphuric acid and Chloride of Calcium (thus suffering the most complete desiccation the Chemist can effect), and yet have not lost their vitality. It is singular that in this desiccated condition, they may be heated to a temperature of 250°, without the destruction of their vitality; although, when in full activity, they will not sustain a temperature of more than from 112° to 115°. Some of the minute Entomostracous Crustacea, which are nearly allied to the Rotifera, appear to partake with them in this curious faculty. Many instances are on record, in which Snails and other terrestrial Mollusca have revived, after what appeared to be complete desiccation; and the *eggs* of the Slug, when dried up by the sun or by artificial heat, and reduced to minute points only visible with the Microscope, are found not to have lost their fertility, when they are moistened by a shower of rain, or by immersion in water, which restores them to their former plumpness. Even after being treated eight times in this manner, the eggs were hatched when placed in favourable circumstances; and even eggs in which the embryo was distinctly formed, survived such treatment without damage. That such capability should exist in the animals and eggs just mentioned, shows a remarkable adaptation to the circumstances in which they are destined to exist; since were it not for their power of surviving desiccation, the races of Wheel-Animalcules and Entomostraca must speedily become extinct, through the periodical drying-up of the small collections of water which they inhabit; and a season of prolonged drought must be equally fatal to the terrestrial Mollusca.

160. It would seem that many cold-blooded animals are reduced, by a moderate deficiency of fluid, to a state of torpidity closely resembling that induced by cold; and hence it is, that during the hottest and driest part of the tropical year, there is almost as complete an inactivity, as in the winter of temperate regions. The common Snail, if put into a box without food, constructs a thin operculum or partition across the orifice of the shell, and attaches itself to the side of the box: in this state it may remain dormant for years, without being affected by any ordinary changes of temperature; but it will speedily revive if plunged in water. Even in their natural haunts, the ter-

restrial Mollusca of our own climates are often found in this state during the summer, when there is a continued drought; but with the first shower they revive and move about. In like manner it is observed that the rainy season, between the tropics, brings forth the hosts of insects, which the drought had caused to remain inactive in their hiding-places. Animals thus rendered torpid seem to have a tendency to bury themselves in the ground, like those which are driven to winter-quarters by cold. Mr. Darwin mentions that he observed, with some surprise, at Rio de Janeiro, that, a few days after some little depressions had been changed into pools of water by the rain, they were peopled by numerous full-grown shells and beetles.

161. This torpidity consequent upon drought is not confined to Invertebrated animals. There are several Fish, inhabiting fresh water, which bury themselves in the mud when their streams or pools are dried up, and which remain there in a torpid condition until they are again moistened. This is the case with the curious *Lepidosiren*, which forms so remarkable a connecting link between Fishes and the Batrachian Reptiles; it is an inhabitant of the upper parts of the river Gambia, which are liable to be dried up during much more than half the year; and the whole of this period is spent by it in a hollow which it excavates for itself deep in the mud, where it lies coiled up in a completely torpid condition,—whence it is called by the natives the *sleeping-fish*. When the return of the rainy season causes the streams to be again filled, so that the water finds its way down to the hiding-place of the Lepidosiren, it comes forth again for its brief period of activity; and with the approach of drought, it again works its way down into the mud, which speedily hardens around it into a solid mass. In the same manner, the *Proteus*, an inhabitant of certain lakes in the Tyrol, which are liable to be periodically dried up, retires at these periods to the underground passages that connect them, where it is believed to remain in a torpid condition; and it thence emerges into the lakes, as soon as they again become filled with water. The Lizards and Serpents, too, of tropical climates, appear to be subject to the same kind of torpidity, in consequence of drought, as that which affects those of temperate regions during the cold of winter. Thus Humboldt has related the strange accident of a hovel having been built over a spot, where a young Crocodile lay buried, alive though torpid, in the hardened mud; and he mentions that the Indians often find enormous Boas in the same lethargic state; and that these revive when irritated or wetted with water.—All these examples show the necessity of a fixed amount of fluid, in the animal structure, for the maintenance of vital *activity;* whilst they also demonstrate, that the preservation of the vital *properties* of that structure is not always incompatible with the partial, or even the complete, abstraction of that fluid; the solid portions being then much less liable to decomposition by heat, or by other agencies, than they are in their ordinary condition.

CHAPTER III.

OF THE ELEMENTARY PARTS OF ANIMAL STRUCTURES.

162. In the investigation of the operations of a complex piece of Mechanism, and in the study of the forces which combine to produce the general result, experience shows the advantage of first examining the component parts of the Machine,—its springs, wheels, levers, cords, pulleys, &c.,—determining the properties of their materials, and ascertaining their individual actions. When these have been completely mastered, the attention may be directed to their combined actions; and the bearing of these combinations upon each other, so as to produce the general result, would be the last object of study.

163. This seems the plan which the Student of Physiology may most advantageously pursue, in the difficult task of making himself acquainted with the operations of the living fabric, and with the mode in which they concur in the maintenance of Life. He should first examine the properties of the component materials of the structure in their simplest form; these he will find in its nutrient fluids. He may next proceed to the simplest forms of organized tissue, which result from the mere solidification of those materials, and whose properties are chiefly of a mechanical nature. From these he will pass to the consideration of the structure and vital actions of those tissues that consist chiefly of cells; and will investigate the share they take in the various operations of the economy. Next his attention will be engaged by the tissues produced by the transformation of cells; of which some are destined chiefly for affording mechanical support to the fabric, and others for peculiar vital operations. And he will be then prepared to understand the part, which these elementary tissues severally perform in the more complex organs. A due knowledge of these elementary parts, and of their physical, chemical, and vital properties, is essential to every one who aims at a *scientific* knowledge of Physiology. True it is, that we may study the *results* of their operations, without acquaintance with them; but we should know nothing more of the *working* of the machine, than we should know of a cotton-mill, into which we saw cotton-wool entering, and from which we saw woven fabrics issuing forth; or of a paper-making-machine, which we saw fed at one end with rags, and discharging hot-pressed paper, cut into sheets, at the other. The study of these results affords, of course, a very important part of the knowledge we have to acquire respecting the operations of the machine; but we could learn from them very little of the nature of the separate processes effected by it; still less should we be prepared, by any disorder or irregularity in the general results, to seek for, and rectify,

the cause of the disturbance in the working of the machine, by which the abnormal result was occasioned.

164. Now just as in a Cotton-mill, there are machines of several different kinds, adapted to effect different steps of the change, by which the raw material is converted into the woven fabric, so do we find that in the complex animal fabric there is a great variety of *organs* for performing the several changes, by which the fabric itself is built up and maintained in a condition fit for the performance of its peculiar operations. These operations are the phenomena of sensation, of spontaneous motion, and of mental action. They are the great objects of *Animal* existence; just as the combination of elements into organic substances, that are to furnish the materials of the Animal fabric, seems to be the great purpose of *Vegetative* Life. The vital phenomena which are peculiar to Animals, are manifestations of the properties of certain forms of organized matter,—the Nervous and Muscular tissues,—which are restricted to themselves; just as those which are common to Animals and Plants, are effected by organized structures, which are found alike in both kingdoms. Here, then, we have the essential distinction between these kingdoms;—namely the presence in Animals of a peculiar apparatus, and the consequent possession by them of peculiar endowments, which are totally wanting in Plants. In the lowest forms of Animal life, we are obliged to infer the presence of the characteristic structure, from the obvious existence of the peculiar endowments; the minuteness of their entire fabric being such, as to prevent the discovery of distinct muscular and nervous fibres. But there are many species, indeed whole tribes, in which it is impossible to say with certainty, how far sensibility and spontaneity of action may be justly inferred from the movements they exhibit; and as other distinguishing characters are deficient, it is undetermined (and perhaps will ever remain so) to which kingdom they ought to be assigned.

165. All the operations, then, which are common to Animals and Plants, are concerned in the building-up of the organized fabric, in the maintenance of its integrity, and in the preparation of the germs of new structures, to compensate for the loss of the parent by death. These operations, as formerly explained (§ 44), involve a series of very distinct processes; which, although all performed by the simple cell of the humblest plant, are distributed in more complex structures through a number of parts or organs; whose several actions are almost as separate as those of the dissimilar machines of the cotton-mill,—although, like them, sustained by the same powers, and so far mutually dependent, that neither of them can be suspended without in a short time putting a stop to the rest. Now just as in each of the machines of the cotton-mill we may have similar elements,—such as wheels, levers, pulleys, bands, &c.,—put together in different methods, and consequently adapted for different purposes, as carding, spinning, weaving, &c., so shall we find in the animal body, that these different organs are composed of very similar elements, and that

the individual actions of these elementary parts are the same; but that the difference of result is the consequence of the variety in their arrangement. Thus we shall find that the growth of cells, their absorption of certain matters from the surrounding fluids, and their subsequent liberation of these by the bursting or liquefying of the cell-wall when their term of life is come to an end, are means employed in one part of the body to introduce nutrient materials into the current of the circulation, whilst in another the same processes are used as means to withdraw, from that very same current, certain substances of which it is necessary to get rid. Now certain combinations of elementary structure, adapted to the performance of a set of actions tending to one purpose, and thus resembling one of the machines of a cotton-mill, is termed an *organ;* and the sum-total of its actions is termed its *function*. Thus we have in the function of Respiration, which essentially consists of an interchange of oxygen and carbonic acid between the air and the blood, a multitude of distinct changes, some of them of a character apparently not in the least related to it, but all necessary, in the higher and more complex fabric, to bring the blood and the air into the necessary relation. The sum-total of these changes constitutes the *function* of Respiration; and the structures by which they are effected are *organs* of Respiration.

166. The whole organized structure, then, may be regarded as made up of distinct *organs*, having their several and (to a certain extent) independent purposes; and these organs may be resolved, in like manner, into simple *elementary parts*, whose structure and composition are the same, in whatever part of the fabric they occur. And in like manner, the phenomena of Life, considered as a whole, may be arranged under several groups or *functions*, according to the immediate purpose to which they are directed; and yet in every one of these groups, we shall find repeated the same *elementary changes* which are concerned in the rest. Thus in the act of Respiration, the same kind of muscular movements, the same sort of nervous agency, are concerned, as contribute to the ingestion of the food; and a similar circulation of the blood, to that which supplies the materials for the nutrition of the tissues. Hence we see the propriety of applying ourselves first to the consideration of the elementary parts of the living structure, and of the properties by which they effect the changes, that are characteristic of its several organs.

1. *Of the original Components of the Animal Fabric.*

167. As we can best study the original Components of the Animal Fabric, by investigating their properties before the process of Organization begins, or whilst it is taking place, we must have recourse for this purpose to the nutrient fluid,—the Blood,—in which these are contained in the state most completely prepared for the reception of the Vitalizing influence. The same substances may be found, in an earlier stage of preparation, in the Chyle and Lymph; and also in the

Eggs of oviparous animals. The circumstances attending the development of the latter afford, indeed, the most satisfactory proof of the convertibility of the simple chemical product, Albumen, with certain inorganic substances, into every form of organized structure. For the *white* of the egg consists of nothing else than albumen, combined with phosphate of lime; whilst the *yelk* is chiefly composed of the same substance, mingled with oily matter, and a minute quantity of sulphur, iron, and some other inorganic bodies. Yet this albumen and fatty matter are converted by the germ, after the lapse of a few days, under the simple stimulus of an elevated temperature, into a complex fabric, composed of bones, muscles, nerves, tendons, ligaments, cartilages, fibrous membranes, fat, cellular tissue, &c. &c., and endowed with the properties characteristic of all these substances, which, when brought into consentaneous activity, manifest themselves in the Life of the chick. In tracing these wonderful transformations, therefore, we should rightly commence with *Albumen*. But as recent Chemical researches have shown, that this may be considered as a compound of the more simple substance termed *Proteine*, with Phosphorus and Sulphur, and as its relations to the compounds formed in Vegetable growth are thereby rendered more apparent, it will be desirable to commence with the latter, which has been truly said to be the most universally-present, and most important to life, of all the substances known to the Organic Chemist.

168. *Proteine* may be detected in almost every part of the Vegetable as well as of the Animal fabric, in various conditions and states of combination; being found in a soluble form in their fluids, and in an insoluble state in their solid parts. It may be obtained by dissolving boiled Albumen in a weak solution of caustic alkali; and by then neutralizing the liquid by an acid, which causes its precipitation in the form of grayish-white flocks. And it may also be obtained from the Gluten of wheat flour (the substance which is left when dough is washed with water so as to separate the starch from it), by the very same process. After being washed, it is gelatinous, of a grayish colour, and semi-transparent; when dried, it is yellowish, hard, easily pulverized, tasteless, insoluble in water and alcohol, and decomposed by heat without fusing. There is no perceptible difference, either in elementary composition, or in chemical relations with other substances, between the two specimens of Proteine thus obtained by the same process from the Animal and Vegetable kingdoms. They are both composed, according to Mulder, of 40 Carbon, 31 Hydrogen, 5 Nitrogen, and 12 Oxygen;* they are rendered soluble by alkalies, and are precipitated again by acids; and they form with the latter and with oxygen, definite chemical compounds, from which the combining equivalent just stated is determined. Proteine unites also with Sul-

* The formula of Liebig is different; being 48 Carbon, 36 Hydrogen, 6 Nitrogen, 14 Oxygen. That of Mulder agrees equally well with the proportions of the elements, as deduced from analysis; and seems to represent more accurately the *combining equivalent* of this substance.

phur and Phosphorus, in various proportions; and it is never found free from these, or in a simple uncombined state.

169. The azotized substances obtained from Plants, which have received the names of *Vegetable Albumen*, *Vegetable Fibrin*, and *Vegetable Casein*, are all compounds of proteine with the last-named elements; but the exact amount of the latter has not been certainly ascertained in each case; the proportion they bear to the proteine being so small, as to render the analysis difficult. These proteine-compounds are found in the youngest parts of the roots of plants; and are probably formed there, and transported by the circulation of the sap into distant parts. The milk-white colour of certain vegetable juices is partly due to the large quantity of these substances which they contain. The deposition of the proteine-compounds in certain groups of cells, in a solid condition, would be sufficiently accounted for by the agency of an acid, which changes it from its soluble to its insoluble form; whilst, on the other hand, its removal from one set of cells, and its transference to others, might be accomplished by an alkaline solution, which would re-dissolve it. That such a transference really does take place, appears from the fact, that the proportion of the proteine-compounds contained in old cells is much less than that of the young and growing parts; from which, therefore, it seems to be removed at a subsequent time. The principal differences in the properties of the three compounds above named are these. Vegetable Albumen, and Legumin or Vegetable Casein, are both of them soluble in cold water; but the former is coagulated by heat, and may be obtained in this manner from the fresh saps of most plants; whilst the latter is not coagulated by heat, but may be precipitated by acids from water in which the meal of peas or beans has been soaked. The substance termed Vegetable Fibrin, or more correctly Coagulated Vegetable Albumen, is insoluble in water; and is the azotized matter existing in the seeds of corn, in almonds, &c., which is not taken up by water. Besides these, there is another termed *glutin* to be obtained from wheat flour, by the agency of alcohol, in which it is soluble.

170. It is certain that the proteine-compounds of Plants are transferred into the bodies of Animals, and become, with little or no change, the materials of their organizing processes. Whether similar compounds may be formed within the animal body, at the expense of any of the other materials supplied by plants, has not yet been certainly ascertained; but the preponderance of evidence appears on the negative side. According to Mulder, the proportions in which Sulphur and Phosphorus are united with Proteine, in the Animal body, are as follows:—in the Albumen of blood-serum, 2 Sulphur, and 1 Phosphorus, to 10 Proteine;—in Fibrin and the Albumen of eggs, 1 Sulphur, and 1 Phosphorus, to 10 Proteine;—in Casein, 1 Sulphur to 10 Proteine;—and in the substance of which the Crystaline lens of the eye is chiefly made up, 1 Sulphur to 10 Proteine. The small proportion of the additional elements is no argument against their being of great importance in the constitution of these bodies; for Inorganic Chemistry

furnishes numerous examples, in which the presence or absence of a body that bears a very small proportion to the whole, makes a vast difference in the properties of the compound. Thus Arseniuretted Hydrogen, which is one of the most poisonous of all gases, contains less than 2 per cent. of Hydrogen; yet it is to this small quantity, that the peculiar character and gaseous state of this compound are owing. Still more remarkable is the fact mentioned by Sir J. Herschel, that by alloying mercury with *a millionth* of its weight of sodium, a power of not less than 50,000 times that of gravity is instantaneously generated, when the alloy is submitted to galvanic influence.—It cannot be doubted, however, from considerations presently to be stated, that a far greater difference exists between animal *Albumen* and animal *Fibrin*, than between any of the corresponding principles in Plants; and that this difference is due much less to diversity in composition (for according to Mulder, the amount of all the components is the same in the Fibrin of blood and in the Albumen of the egg), than to a change in the arrangement of the ultimate particles.

171. According to Mulder, Proteine unites with Oxygen in definite proportions, so as to form a *binoxide* and a *tritoxide*. These are both produced when Fibrin is boiled in water for some time; the latter being then found dissolved, whilst the former remains insoluble. The *tritoxide* may also be formed by boiling Albumen for some time in water, and is in like manner taken up in solution; but the insoluble residue is still albumen. It is further obtainable by decomposing the chlorite of proteine with ammonia. In its properties it somewhat resembles gelatin, and has been mistaken for that substance. There is reason to think that this compound really exists as such in the blood; a small quantity of it being formed every time that the blood passes through the lungs, and given out again when it returns to the system; and a much larger amount being generated during the inflammatory process, so that it may be easily obtained from the "buffy coat" by boiling. It is also contained in pus, which is a product of the inflammatory process.—The *binoxide* is quite insoluble in water. but dissolves in dilute acids. It may be obtained by dissolving hair in potash, adding a little acid to throw down the proteine, and then adding a large excess of acid, which precipitates the binoxide. According to Mulder, this compound also is produced in small quantity at every respiration; and it enters into the normal composition of several of the animal tissues. These views, however, must still be received with some hesitation.

172. One of the most characteristic and important properties of Proteine, is the facility with which it undergoes decomposition, when acted on by other chemical substances, especially by alkalies. If a proteine-compound be brought into contact with an alkali, ammonia is immediately disengaged; indeed, the alkaline solution can hardly be made weak enough to prevent the disengagement of ammonia. This is a property, which must be continually acting in the living body; since the blood has a decided alkaline reaction. If either albumen,

or any other proteine-compound, be boiled with potash, it is completely decomposed;—not, however, being resolved at once into its ultimate constituents, or altogether into simple combinations of them, but in great part into three other organic compounds, Leucin, Protid, and Erythroprotid.—*Leucin* is a crystaline substance, which forms colourless scales, destitute of taste and odour; it is soluble in water and alcohol, and sublimes unchanged. It consists of 12 Carbon, 12 Hydrogen, 1 Nitrogen, and 4 Oxygen. There is not at present any evidence that it is produced in the living body; and the chief interest which attaches to it arises from the fact, that it may be procured from Gelatin as well as from Proteine; which indicates a near relationship between these two substances.—The two other compounds, *Protid* and *Erythroprotid*, are uncrystaline substances, the former of a straw-yellow, and the latter of a reddish-brown colour; they belong to the class of bodies which was formerly included under the vague general term of *extractive matter;* and both in their chemical composition, and their solubility in water, they bear a strong resemblance to Gelatin. The first of them consists of 13 C, 9 H, 1 N, 4 O; and the second of 13 C, 8 H, 1 N, 5 O; whilst the formula of Gelatin is 13 C, 10 H, 2 N, 5 O.—Besides these substances, Ammonia, with Formic and Carbonic Acids, are produced; the acids unite with the potash, employed to effect the decomposition; and the ammonia is set free.

173. We have next to speak of that one of the proteine-compounds in the living body, which corresponds most closely with those yielded by Plants, and which serves as the material at the expense of which all the rest may be formed, by chemical transformations analogous to the preceding. This is *Albumen;* which exists in solution in the Blood and Chyle; and which makes up the largest part of the yelk, and the whole of the white, of the Egg. In its *soluble* state, it is always combined with a small quantity of free soda, with which it seems to be united as an acid with its base; and to this state of combination, its solubility is regarded by most Chemists as being due. When the fluid in which it is dissolved is evaporated at a low temperature (not exceeding 126°), the Albumen, or rather Albuminate of Soda, may be dried, without losing its solubility; when dried, it may be exposed to a temperature of 212°, without undergoing change; and it forms, when again dissolved in water, the same glairy, colourless, and nearly tasteless fluid as before. When a higher temperature is employed, however, the Albumen passes into the insoluble form; and presents itself either as a cloudy or flocculent precipitate, or as a firm consistent coagulum, according to the strength of the original solution. The same condition regulates the amount of heat requisite for the purpose; thus if the quantity of albumen be so great that the liquid has a slimy aspect, a temperature of 145° or 150° is sufficient for the purpose, and the whole becomes solid, white, and opaque; but in a very dilute condition, boiling is required, and the albumen then separates in the form of white finely-divided flocks. In either case, the soda, and other soluble salts are separated from the albumen

and remain dissolved in the water. When the coagulation of Albumen takes place rapidly, the coherent mass seems quite homogeneous, and shows no trace of anything like definite arrangement; but when the process is more gradual, minute granules present themselves, which do not, however, exhibit a tendency towards any higher form of structure. The insoluble coagulum, or pure Albumen, dries up to a yellow, transparent, horny substance; which, when macerated in water, resumes its former whiteness and opacity.—Pure Albumen may also be obtained from the solid mass, which remains when an Albuminous fluid is dried at a low temperature, by reducing it to a fine powder, and then washing it with cold water on a filter; common salt, with sulphate, phosphate and carbonate of soda, is dissolved out; and a soft swollen mass remains upon the filter, which has all the characters of Albumen, obtained by precipitation, except that it is readily soluble in a solution of nitrate of potash, which will not dissolve the latter substance.

174. Albumen may also be thrown down from its solution, in a coagulated state, by Alcohol, Creasote, and by most Acids, when these are added in excess, so as to do more than neutralize the alkali. Nitric acid is particularly efficacious in occasioning coagulation; on the other hand, Acetic acid, and common or tribasic Phosphoric acid do not precipitate it, these acids having the property of dissolving pure Albumen. In the precipitation of Albumen by an Acid, definite compounds are formed between the two; in which the Albumen acts the part of a base. On the other hand, as already remarked, it serves as an acid in its combinations with the caustic Alkalies, and is held in solution by them. Most of the metallic salts, as those of copper, lead, mercury, &c., form insoluble compounds with albumen, and thus give precipitates with its solution; hence the value of white of egg as an antidote, in cases of poisoning with corrosive sublimate. The best method of detecting the presence of soluble albumen in very small quantity, is to boil the liquid, and add nitric acid; if turbidity is then produced, the existence of albumen may be inferred.

175. The existence of unoxidized Sulphur in Albumen, is shown by the familiar fact of the blackening of a silver spoon by a boiled egg; which is due to the formation of an alkaline Sulphuret during the coagulation. A very important property of soluble Albumen is its power of uniting with Phosphate of Lime, and rendering it soluble; it is in this way, that the consolidating material of bones is introduced into the body. About two per cent. of this salt may be separated from Albumen in its coagulated state.

176. Nearly allied to Albumen is the substance termed *Casein*, which replaces it in Milk; and this is worthy of notice here, because it is the sole form in which the young Mammal receives Proteine into its body, during the period of lactation. Like Albumen, this substance may exist in two forms, the soluble, and the insoluble or coagulated; and it further agrees with it, in requiring, as a condition of its solubility, the presence of a free alkali, of which, however, a

very small quantity suffices for the purpose. It differs from Albumen, however, in this; that it does *not* coagulate by heat, and that it *is* precipitated from its solution by Acetic acid. Casein is further remarkable for the facility with which its coagulation is effected by the contact of certain animal membranes, as in the ordinary process of cheese-making. This change is considered by some Chemists to be due, however, not to any direct action of the membrane upon the casein, but to its influence in converting some of the milk-sugar into lactic acid, which, separating the alkali of the casein, will occasion the precipitation of the latter. The only difference which can be detected between Albumen and Casein, in regard to the proportions of their elements, consists in the absence of Phosphorus in the latter; but this can scarcely be the cause of the foregoing differences in their properties. Casein appears to surpass Albumen in its power of combining with the phosphates of lime and magnesia, and rendering them soluble.

177. Albumen and Casein, then, may be regarded as constituting the raw materials, at the expense of which the organized tissues of the Animal fabric are built up; and we have sufficient evidence, in the development of the Chick from the egg, and of the young Mammal from milk, that they may be transformed into *any* of the proteine compounds which are to be found in the Animal body. How far they may require to be united with fatty matter in producing some of these, —as the Nervous,—can scarcely be yet determined; but it is a circumstance worthy of note, that in both the foregoing cases, fatty matter is mingled with the albumen, in the aliment destined for the development of the young animal. The purpose of this, however, may be nothing else than the production of the Adipose tissue, and the maintenance of the respiration.—Further evidence that Albumen is the raw material of the Animal tissues, is derived from this;—that it is the form to which all the proteine-compounds contained in the food, whether derived from the Animal or from the Vegetable kingdom, are reduced by the Digestive process; and in which, therefore, they must be first received within the living system.

178. We find, however, in the fluids that are formed at the expense of this Albumen in the living body, namely the Chyle and the Blood, another substance; which is so closely related to Albumen in its ultimate Chemical composition, as not to be distinguishable from it with any degree of certainty; but which yet differs from it in some of its chemical properties, and still more in the tendency which it exhibits to assume the *organized* form and to manifest *vital* properties. This substance is named *Fibrin.** It is found in the Chyle or crude blood, soon after it is drawn from the food; it presents itself in gradu-

* According to the analyses of Dumas, there is a slight difference between Fibrin and Albumen in ultimate composition; the former having less Carbon, and more Azote than the latter. The difference, however, is so trifling, that it may be doubted whether the Analytical process is yet sufficiently certain and definite to substantiate it.

ally-increasing proportion, as the Chyle slowly passes along the Lacteal vessels, and through the Mesenteric glands, towards the termination of the Absorbent system in the Venous; and it is also found in the fluid contents of that other division of the Absorbent system, the Lymphatics, which is distributed through the body at large, and which seems to have for its chief office to take up, and to re-introduce into the circulating current, such particles contained in the fluids of the tissues, as do not require to be at once cast out of the body, but may be again employed in the process of Nutrition. But it is found, above all, in the Blood,—the fluid whose ceaseless and rapid course through the body supplies to every element of the structure the materials of its growth and development: and the varying proportions in which it presents itself there, are evidently closely connected with the formative powers of that fluid. It is also a principal element of certain colourless *exudations*, which are poured forth from wounded or inflamed surfaces, or which are deposited in the interstices of inflamed tissues; these exudations, when possessed of a high formative property (that is, a readiness to produce an organized tissue), are said to be composed of *coagulable* or *organizable lymph*, which is nothing more than the fibrinous element of the blood, in an unusually concentrated state. We shall first notice the Chemical properties of Fibrin; and shall then inquire into those, which present the first dawnings or indications of Vitality.

179. Like the other Proteine-compounds, *Fibrin* may exist in solution, or in an insoluble form; but there is this important difference,—that its soluble form is not a permanent one, and cannot be maintained in any fibrinous fluid that has been drawn from the living vessels, without the influence of re-agents, which totally destroy its peculiar properties. All investigations of a Chemical nature, therefore, must be made upon insoluble Fibrin; and this may be obtained in its purest state, by whipping fresh blood with a bundle of twigs, by which operation, it will be caused, in coagulating, to adhere to the twigs, in the form of long, white, elastic filaments, with scarcely an admixture of foreign matter. When dried in vacuo, or at a gentle heat, it becomes translucent and horny; and in this condition, it closely resembles coagulated albumen. It further resembles that substance, in being soluble in very dilute caustic alkali, and in phosphoric acid; and the solutions exhibit many of the properties of the similar solutions of albumen. When the fibrin of venous blood is triturated in a mortar with a solution of nitrate of potash, and the mixture is left for twenty-four hours or more at a temperature of from 100° to 120°, it becomes gelatinous, slimy, and eventually entirely liquid. In this condition, it exhibits all the properties of a solution of Albumen which has been neutralized by acetic acid. It coagulates by heat; it is precipitated by alcohol, corrosive sublimate, &c.; and, when largely diluted, it deposits a flocculent substance, not to be distinguished from insoluble albumen. The close Chemical relation of Fibrin and Albumen is further proved by the ready conversion of the former into the latter in the act of di-

gestion; Animal flesh, which consists of Fibrin, being reduced to the form of Albumen with the same facility as the Vegetable compounds, which resemble the latter much more closely in the first instance. The Fibrin of arterial blood, however, cannot be reduced to the fluid form by solution with nitre; and this appears to be due to the oxidized condition of its Proteine; for in a solution of Venous fibrin in nitre, contained in a deep cylindrical jar, and having its surface freely exposed to the air, a fine flocculent precipitate is gradually seen to form; and this, when collected, is found to have the properties of arterial fibrin. The Fibrin of Animal flesh agrees with that of venous, rather than with that of arterial blood. Fibrin, like Albumen, unites with acids as a base, forming definite compounds; and with bases as an acid. It also possesses the property of uniting with the earthy phosphates; of which from ·7 to 2·5 per cent. are found in the ash that is left after its combustion.

180. We see, then, that when considered in its simply-Chemical relations, Fibrin does not differ in any essential particular from Albumen; and that the chief point of obvious variation, is the *spontaneous* coagulation of the former, when it is removed from the living body. There is, however, in the structure of the coagulum itself, a most important difference; for instead of consisting of a homogeneous structureless mass, or of a simple aggregation of minute granules, it is found by the Microscope, to possess a definite *fibrous* arrangement, the fibres crossing one another in every direction. In the ordinary coagulum or clot of Blood, these fibres do not present any great degree of firmness: they may be hardened, however, by boiling; and their arrangement then becomes more definite. They may be seen much more clearly, however, in the "buffy coat" of Inflammatory blood; in which there is not only an increased proportion of Fibrin, but the Fibrin itself seems to have undergone a higher elaboration,—that is, to have proceeded still further in the change towards regular organization. In this state, the process of coagulation is unusually slow; the clot formed by the fibrous tissue is much more solid; and it continues for some hours, or even days, to increase in solidity, by the mutual attraction of the particles composing the fibres, which causes them to contract and to expel the fluid contained in their interstices.

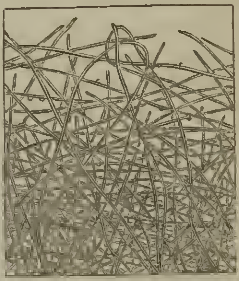
181. The most perfect fibrous structure originating in the simple coagulation of fibrin is to be found, however, in those exudations which take place either from inflammation, or from a peculiar formative action, destined to repair an old tissue or to produce a new one. Thus in Fig. 2 is shown the fibrous structure of a false membrane formed by the consolidation of a fibrinous exudation from the surface of an inflamed peritoneum. And in Fig. 3 is displayed a similar fibrous structure (in which, however, the fibres have more of a reticulated arrangement), which incloses the fluid contents of the egg, and enters into the composition of the shell itself. As the ovum (which, at the time of its quitting the ovarium, consists of the yelk-bag only) passes along the oviduct of the parent, it receives its coating of albuminous

matter, of which layer after layer is thrown out by the vessels of the oviduct. When a sufficient supply has thus been furnished, it appears

Fig 2.

Fibrous structure of inflammatory exudation from peritoneum.

Fig. 3.



Fibrous membrane, lining the egg-shell, and forming the animal basis of the shell itself.

that fibrinous instead of albuminous matter is poured forth; and this, in coagulating, forms a very thin layer of fibrous tissue, which envelops the albumen. Layer after layer is gradually added; and at last, by the superposition of these layers, that firm tenacious membrane is formed, which is afterwards found lining the egg-shell. The process is then continued, with this variation, that carbonate of lime is also secreted from the blood in a chalky state; and its particles lie in the interstices of the fibrous network, and give it that solidity which is characteristic of the shell. If they be removed by the agency of a weak acid, or if the bird be not sufficiently supplied with lime at the time of laying, the outer membrane has the same consistence as the inner; and either may be separated, after prolonged maceration, by dextrous manipulation, into a series of layers of a fibrous *matting* like that represented in Fig. 3.

182. It is scarcely possible to deny to such a tissue the designation of an organized structure, even though it contains no vessels, and may not participate in any further Vital phenomena. We shall hereafter find, that a tissue presenting very similar characters forms a large part of the Animal fabric; and that the vessels with which it is copiously supplied, have for their object nothing else than the removal of its disintegrated or decaying portions, and the deposition of new matter in a similar form (§ 194). In the production of new parts, we find this simple fibrous tissue performing the important function of serving as a matrix or bed for the support of the vessels; and as, by the more gradual transformation of the nutritive materials they bring, new and more permanent tissues are formed, the original one gradually undergoes disintegration, and all traces of it are in time lost. This would appear to be the history of the *Chorion* of the Mammalian ovum; which is at first nothing else than a fibrous unvascular bag, formed round the ovum in its passage through the Fallopian tube,

precisely after the manner of the shell-membrane of the Bird's egg; but which is afterwards penetrated by vessels proceeding from the embryo, and in time acquires a new structure (Chap. XI.)

183. The completeness of the production of such a fibrous tissue depends in part, as we have seen, upon the degree of elaboration which the Fibrin has undergone; but in great part also upon the nature of the surface, on which the coagulation takes place. Thus we never find so perfect a membrane formed by the consolidation of the Fibrin out of the living body,—on a slip of glass for example,—as when it takes place on the surface of a living membrane, or in the interstices of a living tissue. This may perhaps be accounted for by the fact, that the coagulation takes place much more slowly in the latter case than in the former; and that the particles may thus have more time to arrange themselves in the definite *fibrillation*, which seems to be their characteristic mode of aggregation:—just as *crystalization* takes place best when the action is slow; and as a substance, whose particles would remain in an amorphous or disunited form if too rapidly precipitated from a solution, may present a most regular arrangement when they are separated from it more slowly. Of this view it would seem to be a confirmation, that the most perfect fibrillation out of the body is usually seen in those cases, in which coagulation takes place least rapidly.

184. The conditions under which the spontaneous coagulation of Fibrin takes place, are best known from the observation of that process as it occurs in the Blood; and although this fluid, as we shall hereafter see, is of a very complex nature, yet as the Fibrin alone is concerned in its coagulation, and as that act appears to take place in the same manner as if no other substance was present, there appears to be no objection to the employment of the phenomena of Blood-coagulation as the basis of our account of the properties of Fibrin.—There can be no doubt, from Microscopical observation of the circulating Blood, that Fibrin is in a state of perfect *solution* in the fluid; and in this condition it remains, so long as it is in motion in the living body. That its fluidity, however, does not depend only upon its movement, is evident from two facts;—first, that no kind of motion seems effectual in preventing the coagulation of the blood, after it has been drawn from the vessels;—and second, that a state of rest within the living body does not immediately produce coagulation; a portion of blood, included between two ligatures in a living vessel, remaining fluid for a long time. On the other hand, it seems certain that the state of vitality of the parts with which the blood is in contact, has a great influence in preserving its fluidity; thus it has been found that, if the Brain and Spinal Cord of an animal be broken down, and by this measure the vitality of the body at large be lowered, clots of blood are formed in their trunks within a few minutes. Nevertheless, a mass of blood effused into a cavity of the living body, undergoes coagulation almost as soon as it would in a dead vessel; but this may be accounted for by the very small surface which is in contact with

the blood, as compared with the mass of the latter. It must be remembered that the circulating blood is continually being subdivided into countless streams; and that each of these passes through the living tissue, in such a manner that all its particles are in close relation with the living surface. Moreover it is probable that the form of matter which we term Fibrin never remains long in that condition, in the ordinary state of the system; being continually withdrawn by the nutritive processes, and as continually reformed from the Albumen, by an elaborating action hereafter to be considered. Hence we may regard the state of motion through living vessels, as essential to the permanent continuance of fibrin in the fluid form.

185. The length of time, however, during which Fibrin may remain uncoagulated, after it has been withdrawn from the living body, varies according to various conditions; some of which are not well understood. In the first place, as already remarked, the more elaborated and more concentrated the condition of the Fibrin, the more slowly does it usually coagulate. Thus when a large quantity of blood is drawn at one bleeding, into several vessels, that which flows first takes the longest time to coagulate, and forms the firmest clot; whilst that which is last drawn coagulates most rapidly and with the least tenacity. The coagulation is accelerated by moderate heat, and retarded by cold; but it is not prevented even by extreme cold; for if blood be frozen immediately that it is drawn, it will coagulate on being thawed,—thus preserving its vitality, in spite of the freezing process, like the organized structures of many of the lower animals. Again, the coagulation is accelerated by exposure to air; but it is not prevented, though it is retarded, by complete exclusion from it. Various Chemical agents retard the coagulation, without preventing it; this is the case especially with solutions of the neutral salts. The coagulation is not so firm, however, or the fibrillation so perfect, after the use of these; and there can be no doubt that they modify the properties of the fibrin by acting chemically upon it.

186. After remaining in this condition for a certain length of time, the Fibrin undergoes a further change, which is evidently the result of decomposition; the coagulum becomes soft, and exhibits appearances of putrefaction. This takes place the more rapidly, as the first coagulation was less complete. Thus in the imperfectly-elaborated Fibrin of the Chyle, the coagulum is sometimes so incomplete that it does not separate itself from the serum, and liquefies again in half an hour. In certain states of disease, the solidifying properties of the Fibrin are very much impaired; so that it soon liquefies and decomposes. In these cases, there is scarcely any trace of the characteristic fibrous arrangement of the particles.—On the other hand, the fibrinous coagulum of inflamed blood, as it is more solid, is also more persistent, than that of ordinary blood; and the greatest persistency of all is seen in the fibrous network formed by exudation, as in the cases just now mentioned.

187. The coagulating power of Fibrin,—in other words, its pecu-

liar vital property,—may be destroyed by various causes operating within the living body; so that the blood remains fluid after death. These may be classed under three heads. In the first place, the vitality of the fibrin may be destroyed by substances introduced into the blood from without; which have the power of acting in the manner of *ferments*, and which occasion an obvious chemical change in its condition. This is the case in the severe forms of Typhoid fever, which are termed *malignant;* and especially those which result from the contact of putrescent matter, as Glanders, Pustule maligne, &c. Secondly, it may be impaired or altogether destroyed by morbid actions originating in the system itself, and depending upon irregular nutrition or imperfect excretion; thus the blood has been found fluid after death, in severe cases of Scurvy and Purpura, also in cases of Asphyxia (consequent upon the retention of carbonic acid in the blood), and in the bodies of over-driven animals. The same result may follow, Thirdly, from violent shocks or impressions, which suddenly destroy the vitality of the whole system at once; these may be such as are obviously capable of producing a chemical or mechanical change, as in the case of death by Lightning or by a violent Electrical discharge; or they may act through the nervous system, in a manner not yet clearly understood, as when death results from concussion of the brain, from a blow upon the epigastrium, from violent mental emotion, or from a coup de soleil.—It is not to be supposed that the non-coagulability of the Blood is a phenomenon by any means invariable under the foregoing circumstances; but it has been occasionally observed in all of them. We must not mistake, for the *absence of coagulating power*, the remarkable *retardation of the act of coagulation* which sometimes occurs. Thus, the blood is occasionally found in a fluid condition in the bodies of persons that have been dead for some days; and yet when withdrawn from the vessels it coagulates. An instance has been lately put on record, in which blood drawn from a patient suffering under an attack of pneumonia, did not coagulate for fifteen days, but then formed a firm clot, and was a month before it putrefied.

2. *Of the Simple Fibrous Tissues.*

188. A large part of the Animal fabric, especially among the higher classes in which the parts have the greatest amount of motion upon one another, is composed of tissues, which seem as if they consisted of nothing else than *fibres*, of the simple character already described, woven together in various ways, according to the purposes they are destined to serve. These fibres are altogether different from those hereafter to be described as constituting the Muscular and Nervous tissues, and must not be confounded with them. The former are *solid*, and possess none but *physical* properties; the latter are *tubular*, and are distinguished by their peculiar *vital* endowments, which seem chiefly, if not entirely, to reside in the *contents* of the tubular fibre.

The simple fibrous tissues, of which we have now to treat, appear to have for their sole office in the animal body to bind together the other elementary parts into one whole, without uniting them so closely as to render them immovable; and we find the same elements arranged in very different modes, according to the purposes they are destined to fulfil. Thus in the *Tendons*, by which the Muscles are connected with the Bones and impart motion to them, the only property required is that of resisting strain or tension in *one* direction; and in these we find the fibres disposed in a parallel arrangement, passing continuously in straight lines between the points of attachment. In the *Ligaments* which connect the bones together, and which also have for their purpose to afford resistance to strain, but which are liable to tension in a greater variety of directions, we find bundles of fibres crossing each other according to these directions; and in some instances we find the ligaments endowed also with a certain degree of elasticity. The structure of the strong *Fibrous Membranes*, which form the envelops to different organs and bind together the contained parts, is very similar; each of these membranes being composed of several layers of a dense network, formed by the interweaving of bundles of fibres in different directions. In the *Fibro-Cartilages*, we find a mixture of the characteristic structure of Ligament with that of Cartilage; bundles of fibres, similar to those which constitute the former, being disposed among the cells which are the chief organized constituents of the latter. In certain Fibro-Cartilages, however, these fibres are endowed with a high degree of elasticity.

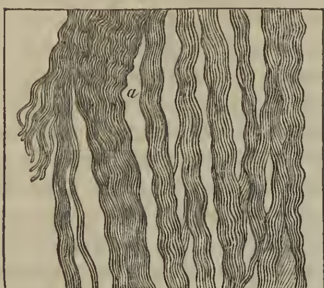
Fig. 4.

Simple fibrous tissue; *a*, fibres of areolar tissue; *b*, tendinous fibres.

189. These two qualities,—that of resistance to tension without any yielding,—and that of resistance combined with elasticity,—are characteristic of two distinct forms of Fibrous tissue, the *White* and the *Yellow*. The *White Fibrous* tissue presents itself under various forms; being sometimes composed of fibres so minute as to be scarcely distinguishable; and sometimes presenting itself under the aspect of bands, usually of a flattened form, and attaining the breadth of 1-500th of an inch. These bands are marked by numerous longitudinal streaks, but they cannot be torn up into minute fibres of determinate size; hence they must be regarded as made up of an aggregation of the same elements as those which may become developed into separate fibres. The fibres and bands are occasionally somewhat wavy in their direction. This tissue, which is perfectly inelastic, is easily distinguished from the other by the effect of Acetic acid, which swells it up and renders it transparent, at the same time bringing into view certain oval corpuscles, which are supposed to be the nuclei of

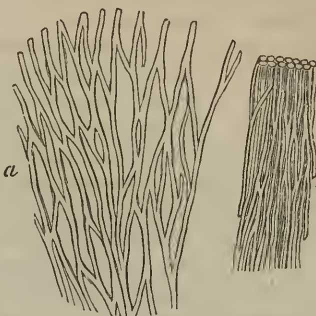
the cells that were concerned in the formation of the tissue.—The *Yellow Fibrous* tissue exists in the form of long, single, elastic, branched

Fig. 5.



Fasciculus of fibres of white fibrous tissue from lateral ligament of knee-joint.

Fig. 6.



Yellow fibrous tissue from ligamentum nuchæ; *a*, the fibres drawn apart, to show their reticulate arrangement; *b*, the fibres in situ.

filaments, with a dark decided border; which are disposed to curl when not put on the stretch. They are for the most part between 1-5000th and 1-10,000th of an inch in diameter; but they are often met with both larger and smaller. They frequently anastomose, so as to form a network, as shown in Fig. 6. This tissue does not undergo any change, when heated with acetic acid. It exists alone (that is, without any mixture of the white), in parts which require a peculiar elasticity, such as the middle coat of the Arteries, the Chordæ Vocales, the Ligamentum Nuchæ (of Quadrupeds), and the Ligamenta subflava; it enters largely into the composition of certain parts, which are commonly regarded as Cartilaginous, such as the external ear; and it is also a principal component of other tissues to be presently described.

190. These tissues are very different in Chemical composition. Those which are composed of the White fibrous element,—namely, Tendons, Ligaments, &c.—are almost entirely resolved by long boiling into the substance termed *Gelatin* or Glue; and this is also largely obtained from the skin, and from Mucous and Serous Membranes, into which, as we shall presently see, that element enters largely. The composition of Gelatin is much simpler than that of the Protein-compounds; so far, at least, as regards the number of atoms of its several elements; for it consists (according to Mulder) of 13 Carbon, 10 Hydrogen, 2 Nitrogen, 5 Oxygen. This composition is the same, whether the Gelatin be obtained from isinglass, from fibrous membranes, or from bones. The distinctive characters of Gelatin are its solubility in warm water, its coagulation on cooling into a uniform jelly, and its formation of a peculiar insoluble compound with Tannic acid. Gelatin is very sparingly soluble in cold water; though prolonged contact with it will cause the Gelatin to swell

up and soften. Its power of forming a jelly on cooling is such, that a solution of one part in 100 of water will become a consistent solid. And its reaction with Tannic acid is so distinct, that the presence of one part of Gelatin in 5000 of water is at once detected by infusion of Galls.—There can be no doubt that Gelatin does not exist *exactly as such* in the Fibrous tissues; since none can be dissolved out of them by the continued action of cold water, and it usually requires the *prolonged* action of hot water, to occasion their complete conversion. There are some substances, however, in which this is not requisite; and from which the gelatin may be more readily extracted. This is the case, for example, with the air-bladder of the Cod and other fish; which, when cut into shreds and dried, is known as Isinglass. It is the case also with the substance of bones, from which the calcareous matter has been removed. In both instances it would seem that the state of organization is very imperfect; scarcely any traces of the fibrous structure being perceptible. When the fibrous arrangement is more complete, the solubility of the tissue is much diminished. Hence it would seem that the particles have a different arrangement in the tissues, from that which they have in the product obtained by boiling. Their ultimate composition, however, is the same; for when any serous membrane, or other tissue principally composed of the white fibrous element, is analyzed by combustion, the elements are found to have the same proportion to each other as in Gelatin, allowance being made for the small admixture of other substances. The action of Tannic acid, too, is the same on the organized tissue, as it is on the gelatin extracted from it; and hence results its utility in producing an insoluble compound, not liable to undergo decomposition, in the substance of the skin, converting it into leather.

191. It is not yet known how Gelatin is produced in the Animal body. There can be no doubt that it may be elaborated from Albumen; since we find a very large amount of Gelatin in the tissues of young animals, which are entirely formed from albuminous matter; and also in the tissues of herbivorous animals, which cannot receive it in their food, as Plants yield no substance resembling gelatin. It has been suggested by Mulder, that Gelatin may be formed by the decomposition of Protein, which has been already mentioned as taking place from the agency of weak Alkaline solutions, (§ 172,) and which must probably, therefore, be continually occurring in the blood. For if to each atom of Protid and Erythroprotid, we add one of the atoms of Ammonia, which are given off in that decomposition, we have compounds, of which the former differs from Gelatin only by the presence of two additional atoms of hydrogen and the deficiency of one of oxygen, whilst the only difference in the latter consists in the presence of one additional atom of hydrogen. Thus the ammoniated erythroprotid, when exposed to oxygenation in the lungs, may have its one superfluous atom of hydrogen carried off in the form of water, and will then have the composition of Gelatin; and the same result

will be obtained from the ammoniated protid, by the addition of three atoms of oxygen, which will convert it into gelatin and two atoms of water. These transformations must be regarded for the present as altogether *theoretical;* but it does not appear at all unlikely that they may *really* take place.

192. The composition of the *Yellow* fibrous tissue appears to be altogether dissimilar. It scarcely undergoes any change by prolonged boiling; it is unaffected also by the weaker acids; and it preserves its elasticity, if kept moist, for an almost unlimited period. According to Scherer it consists of 48 Carbon, 38 Hydrogen, 6 Nitrogen, and 16 Oxygen; and he considers it to be composed of an atom of Proteine with two atoms of water. (See § 168, *note.*)

193. The simple Fibrous tissues appear to be very little susceptible of change in the living body; and we find them very sparingly supplied with blood-vessels. In the solid Tendons, the bundles of straight parallel fibres are a little separated from each other by the intervention of the Areolar tissue to be presently noticed; and this permits the sparing access of vessels to their interior. In the Fibrous Membranes and Ligaments, this is found in somewhat larger amount; and the vascularity of these tissues is rather greater.

194. The great use of the foregoing Tissues appears to be, to afford a firm resistance to tension; by which they may either communicate motion, as in the case of Tendons; or restrain it, as in the case of Ligaments; or altogether prevent it, as in the case of Aponeuroses and Fibrous Membranes. With this firm resistance, a considerable amount of elasticity may be combined. But we have now to notice a tissue, in which a very different arrangement of the same elements presents itself; and the object of this is, to bind together the elements of the different fabrics of the body, and at the same time to endow them with a greater or less degree of freedom of movement upon one another. This tissue, which is called the *Areolar*, consists of a network of minute fibres and bands, which are interwoven in every direction, so as to leave innumerable *areolæ* or little spaces, which communicate freely with one another. Of these fibres, some are of the yellow or elastic kind; but the majority are composed of the white fibrous tissue, and, as in that form of elementary structure, they frequently present the form of broad flattened bands, or membranous shreds, in which no distinct fibrous arrangement is visible. The interstices are filled during life with a fluid, which resembles very dilute serum of the blood, consisting chiefly of water, but containing a sensible quantity of common salt and albumen. This tissue,—which has been frequently but erroneously termed Cellular,—is very extensible in all directions, and very elastic, from the structural arrangement of its elements. It cannot be said to possess any distinctly *vital* endowments; for although it has a certain amount of *sensibility*, this merely depends upon the presence of nerves which it is conveying to other parts; and the small amount of *contractility*

which it shows, depends rather upon the muscular tissue of the vessels that traverse it.

195. As already mentioned, we find this tissue in almost every part of the body; thus it binds together the ultimate fibres of the Muscles into minute fasciculi, unites these fasciculi into larger ones, these again into larger ones which are obvious to the eye, and these into the entire muscle. Again it forms the membranous septa between distinct muscles, or between muscles and fibrous aponeuroses. In like manner it unites the elements of nerves, glands, &c.; binds together the fat-cells into minute bags, these into larger ones, and so on; and in this manner penetrates and forms a considerable part of all the softer tissues of the body. But it is a great mistake to assert, as it was formerly common to do, that it penetrates the harder organs, such as bones, teeth, cartilage, &c. Its purpose obviously is, to allow a certain degree of movement of the parts which it unites; and hence we find it entering much more largely into the composition of the Mammary gland (which, from its attachment to the great pectoral muscle, must have its parts capable of being shifted upon one another), than into that of the Liver, Kidneys, &c. It also serves as the *bed*, in which blood-vessels, nerves, and lymphatics may be carried into the substance of the different organs; and it often undergoes a degree of condensation, in order to form a sheath for the larger trunks, which gives it almost the characters of a Fibrous Membrane.

196. The quantity of fluid in the insterstices of Areolar tissue is subject to considerable variations; but these depend rather upon the state of fullness or emptiness of the vessels which traverse it, and upon the condition of the walls of those vessels, than upon any change in the tissue itself. It has been shown that, when an albuminous fluid is in contact with an animal membrane, the watery part of the fluid will pass through by transudation; but that the albuminous matter will be for the most part kept back, so that only a very small proportion of it is to be found in the transuded liquid. This appears to be a sufficient explanation of the presence of a weak serous fluid in the cavities of areolar tissue; and there is not any necessity, therefore, to imagine the existence of a secreting power, either in the areolar tissue itself, or in the walls of the capillaries which traverse it. When there is a want of firmness or tone in the walls of the vessels, producing (as we shall hereafter see, § 609) an increased pressure of the contained fluid on their walls, and diminished resistance, the watery part of the blood will have an unusual tendency to transudation; and we accordingly find that it then distends the areolæ, and produces *dropsy*. The physical arrangement of the parts of the tissue is so much altered, that its elasticity is impaired; and it consequently *pits* on pressure,—that is, when pressure has made an indentation in the surface, this is not immediately filled up when the pressure is withdrawn, but a *pit* remains for some seconds or even minutes. The free communication which exists amongst the interstices, is shown by the influence of gravity upon the seat of the dropsical effusion; this

always having the greatest tendency to manifest itself in the most depending parts,—a result, however, which is also due to the increased delay, which takes place in the circulation in such parts, when the vessels are deficient in tone. This freedom of communication is still more shown, however, by the fact, that either air or water may be made to pass, by a moderate continued pressure, into almost every part of the body containing Areolar tissue; although introduced at only a single point. In this manner it is the habit of butchers to *inflate* veal; and impostors have thus *blown-up* the scalps and faces of their children, in order to excite commiseration. The whole body has been thus distended with air by emphysema in the lung; the air having escaped from the air-cells into the surrounding areolar tissue, and thence, by continuity of this tissue with that of the body in general at the root or apex of the lungs, into the entire fabric.

197. The structure of the *Serous* and *Synovial* Membranes is essentially the same with that of Areolar tissue. Their free surface is covered with a layer of cells; but these constitute a distinct tissue, the *Epithelium*, of which an account will be given hereafter. The epithelium lies upon a continuous sheet of membrane, of extreme delicacy, in which no definite structure can be discovered; the nature of this, which is called the *basement* or *primary-membrane*, will be presently considered (§ 206). Beneath this is a layer of condensed Areolar tissue, which constitutes the chief thickness of the serous membrane, and confers upon it its strength and elasticity; this gradually passes into that laxer variety, by which the membrane is attached to the parts it lines, and which is commonly known as the *sub-serous* tissue. The yellow fibrous element enters largely into the composition of the membrane itself; and its filaments interlace in a beautiful network, which confers upon it equal elasticity in every direction. The membrane is traversed by blood-vessels, nerves, and lymphatics, in varying proportions; some of the synovial membranes, especially that of the knee-joint, are furnished with little fringe-like projections, which are extremely vascular, and which seem especially concerned in the secretion of the synovial fluid. The fluid of the serous cavities is so nearly the same as the serum of the blood, that the simple act of transudation is sufficient to account for its presence in their sacs; on the other hand, that of the Synovial capsules, and of the Bursæ Mucosæ which resemble them, may be considered as serum with from 6 to 8 per cent. of additional albumen.

198. The elements of Areolar tissue enter largely also into two other textures, which perform a most important share in both the Organic and the Animal functions;—namely, the *Mucous Membranes* and the *Skin*. These textures are continuous with each other; and may, in fact, be considered as one and the same, modified in its different parts according to the function it is destined to perform. Thus it is everywhere extremely vascular; but the supply of blood in the skin is chiefly destined for the nervous system, and is necessary to the act of sensation; whilst that of the internal skin or mucous mem-

brane is rather subservient to the processes of absorption and secretion. This tissue is continued from the external surface of the body by the several orifices and outlets of its cavities; and it is further continued most extensively from its primary internal prolongations, into the inmost recesses of the glandular structures.

199. Thus the *gastro-intestinal* mucous membrane commences at the mouth, and lines the whole alimentary canal from the mouth to the anus, where it again becomes continuous with the skin; and it sends off as branches, the membranous linings of the ducts of the salivary glands, pancreas, and liver; these membranes proceed into all the subdivisions of the ducts, and line the ultimate follicles or cœca in which they terminate. Again the *bronchio-pulmonary* mucous membrane commences at the nose, and passes along the air-passages, down the trachea, through the bronchi and their subdivisions, to line the ultimate air-cells of the lungs; communicating in its course with the gastro-intestinal. Another mucous membrane of small extent commences at the puncta lachrymalia, lines the lachrymal sac and the nasal duct, and becomes continuous with the preceding. Another, which may be considered a kind of offset from either of the first two, passes up from the pharynx along the Eustachian tube, and lines the cavity of the tympanum.

200. Near the opposite termination of the alimentary canal, moreover, we have the *genito-urinary* mucous membranes; these commence in the male by a single external orifice, that of the urethra;—passing backwards along the urethra, the *genital* division is given off, to line the seminal ducts, the vesiculæ seminales, the vasa deferentia, and the secreting tubuli of the testis; another division proceeds along the ducts of the prostate gland, to line its ultimate follicles, and another along the ducts of Cowper's glands; whilst the *urinary* division lines the bladder, passes up along the ureters to the kidney, and then becomes continuous with the membrane of the tubuli uriniferi. In the female, the urinary division commences at once from the vulva; whilst the genital passes along the vagina into the uterus, and thence along the Fallopian tubes to their fimbriated extremities, where it becomes continuous with the serous lining of the abdominal cavity, the peritoneum.

201. Besides the glandular prolongations here enumerated, there are many others, both from the internal and external surface. Thus we have the *Mammary* mucous membrane, commencing from the orifices of the lactiferous ducts, passing inwards to line their subdivisions, and forming the walls of the ultimate follicles. In the same manner the Lachrymal mucous membrane is prolonged from the conjunctival mucous membrane, which covers the eye and lines the eyelids, and which is continuous with the skin at their edges. There are several minute glands, again, in the substance of the skin, and in the walls of the alimentary canal, which need not be here enumerated; but which contribute immensely to the extension of the surface of the mucous membrane; a prolongation of this being the essen-

tial constituent in every one. In their simplest form, these glandulæ are nothing more than little pits or depressions of the surface; these are found both in the Skin and Mucous membrane, and are particularly destined for the production of their protective secretions, hereafter to be described.

202. We have seen, then, that the essential character of the Mucous membranes, as regards their arrangement, is altogether different from that of the serous and synovial membranes. For whilst the latter form shut sacs, the contents of which are destined to undergo little change, the former constitute the walls of tubes or cavities, in which constant change is taking place, and which have free outward communications. Thus in the gastro-intestinal mucous membrane, we have an inlet for the reception of the food and a cavity for its solution, the walls of which are endowed in a remarkable degree with absorbing power, whilst they are also furnished with numerous glandulæ, which pour the solvent fluid into the cavity. On the other hand, it has an outlet, through which the indigestible residuum is cast forth, together with the excretions from the various glands that pour their products into the alimentary tube. In the bronchio-pulmonary apparatus, the same outlet serves for the introduction and for the expulsion of the air; and here, too, is continual change. In other cases, there is but a single outlet; and the change is of a simpler character, consisting merely in the expulsion of the matters eliminated from the blood by the agency of the glands. Now it is, as we shall see hereafter, in the digestion and absorption of food, on the one hand, and in the rejection of effete matters on the other, that the commencement and termination of the nutrient processes consist; and these operations are performed by the system of Mucous-membranes, including in that general term the Skin, which is an important organ of excretion, besides serving as the medium through which sensory impressions of a *general* character are received by the Nervous system.

203. The *Mucous Membrane* may be said, like the serous, to consist of three chief parts;—the epithelium or epidermis covering its free surface;—the subjacent basement-membrane;—and the areolar tissue, with its vessels, nerves, &c., which forms the thickness of the membrane, and connects it with the subjacent parts. The Epidermis and Epithelium alike consist of cells; but the function of the former (which consists of several layers, of which the outer are dry and horny) is simply protection to the delicate organs beneath; whilst that of the latter is essentially connected with the process of Secretion, as will be shown hereafter. The basement-membrane resembles that of the serous membranes; but its separate existence is unusually evident in some parts where it exists alone, as in the tubuli uriniferi of the kidney; whilst it can with difficulty be demonstrated in others, as the skin. The Areolar tissue of Mucous membranes usually makes up the greatest part of their thickness; and it is so distinct from that of the layers beneath, constituting the sub-mucous tissue, as to be readily separable from them. It differs not in any important particular, how-

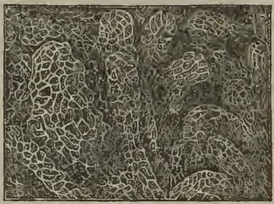
ever, from the same tissue elsewhere; and the white and fibrous elements may be detected in it in varying proportions, in different parts,—the latter being especially abundant in the skin and lungs, which owe to it their peculiar elasticity. Hence the Mucous membranes yield Gelatin in abundance, on being boiled. The skin also appears to contain some of the non-striated Muscular fibre (§ 337), in varying proportions in its different parts.

204. The relative amount of Blood-vessels, Nerves and Lymphatics, as already mentioned, is subject to great variation, according to

Fig. 7.

Distribution of Capillaries at the surface of the skin of the finger.

Fig. 8.



Distribution of Capillaries in the Villi of the Intestine.

the part of the system examined. The first, however, are most constantly abundant, being required in the Skin for sensation, and in the Mucous membranes for absorption and secretion. In fact we might say of many of the mucous membranes, especially those of the glands, that their whole purpose is to give support to the secreting cells, and to convey blood-vessels into their immediate neighbourhood, whence these cells may obtain materials for their development. The Skin is the only part of the whole system which is largely supplied with

Fig. 9.

Distribution of Capillaries around follicles of Mucous Membrane.

Fig. 10.

Distribution of Capillaries around the follicles of Parotid Gland.

Nerves, except the Conjunctival membrane, and the Mucous membrane of the nose; hence the sensibility of the internal mucous membrane is usually low, although its importance in the organic functions is so great. The Skin is copiously supplied with Lymphatics; and the first part of the alimentary canal with Lacteals; some of the glandular organs are also largely supplied with Lymphatics.

Fig. 11.

Distribution of the tactile nerves at the extremity of the human thumb, as seen in a thin perpendicular section of the skin.

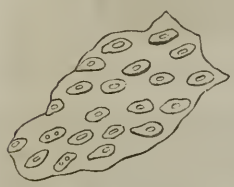
205. The Areolar tissue, whether existing separately, or as forming a part of the Serous and Mucous Membranes, is capable of being very quickly and completely regenerated; indeed, we often find that losses of substance in other tissues are replaced by means of it. As to the precise mode of its production, there is not yet a general agreement amongst Microscopists; some holding that its fibres are produced by the transformation of cells in the manner hereafter to be described (§ 258 and Fig. 33); whilst others regard it as originating in the simple consolidation of Fibrin under peculiar circumstances. To the latter of these opinions the Author inclines; chiefly on account of the strong resemblance between the fibres of Areolar tissue, and those which are unquestionably formed by such a consolidation. It is not to be denied, however, that traces of cells are to be met with amongst these tissues; but as it will be shown that most, if not all, fibrinous exudations contain cells, their presence affords no proof that the mass of fibres have originated in a process of transformation;—the fact that a definite fibrous tissue may have its origin in the coagulation of fibrin, being beyond a doubt.

3. *Of the Basement or Primary Membrane.*

206. In many parts of the Animal body, we meet with membranous expansions of extreme delicacy and transparency, in which no definite structure can be discovered; and these seem, like the simple fibres already described, to have been formed, rather *directly* from the nutritive fluid, than indirectly by any previous process of transformation. Hence we may regard such membranes and fibres as constituting the most simple or elementary forms of Animal tissue. The characters of membranes of this kind were first pointed out by Mr. Bowman and Mr. J. Goodsir; by the former of whom it was termed *basement*-membrane, as being the foundation or resting-place for the epithelium-cells which cover its free surface (§ 231); whilst by the latter it was termed the *primary* membrane, as furnishing the germs of those cells. These terms appear equally appropriate, and may be used indifferently.—In its very simplest form, the basement-membrane is a pellicle of such extreme delicacy, that its thickness scarcely admits of being

measured; it is, to all appearance, perfectly homogeneous, and presents not the slightest trace of structure under the highest powers of the microscope, appearing like a thin film of coagulated gelatin. Examples of this kind may be easily procured, by acting upon the inner layer of any bivalve shell with dilute acid; this dissolves away the calcareous matter and leaves the basement-membrane. In other cases, however, the membrane is not so homogeneous; a number of minute granules being scattered, with more or less of uniformity, through the transparent substance. And we not unfrequently find, in place of these uniformly distributed granules, a series of distinct spots, arranged at equal or variable distances, and in different directions, as shown in Fig. 12. Moreover, the membrane thus constituted is disposed to break up into portions of equal size, each of which contains one of these spots; whilst in the more homogeneous forms previously described, we find no such tendency, no appearance of any definite arrangement being perceptible when they are torn.—Hence it would seem as if the first and simplest form were produced by the simple consolidation of a thin layer of homogeneous fluid; the second, by a layer of such fluid, including granules; and the third, by the coalescence of flattened cells, whose further development had been checked.—We find the primary membrane under one or other of these forms, on *all* the free surfaces of the body, beneath the epithelial or epidermic cells. Thus, as already mentioned, it constitutes the outer layer of the true Skin; it lines all the cavities formed by Mucous membranes, and is prolonged into all the ducts and ultimate follicles and tubuli of the Glands which are connected with them (§ 198); indeed it may be said in many instances to be the sole constituent of the walls of these follicles and tubuli, the subjacent tissue not being continued to their finest ramifications. Again, it forms the innermost layer of the serous and synovial membranes; and it also lines the blood-vessels and lymphatics, forming the sole constituent of the walls of *their* minutest divisions.

Fig. 12.



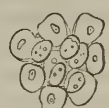
Portion of the primary membrane of the human intra-glandular lymphatics, with its germinal spots, or nutritive centres diffused over it.

207. In every one of these cases, we find the *free* aspect of the primary membrane in contact with *cells*, which form a more or less continuous layer upon its surface. These cells can only receive their nutriment by the imbibition of fluid, through the primary membrane, from the blood brought to its attached surface by the capillary vessels of the tissue with which it is in relation. Thus in the skin and mucous membranes, a very copious supply of blood is brought to the attached surface of the primary membrane, by the minutely-distributed capillaries which form a large part of the subjacent tissue; and it is from these that the epidermis and epithelium draw their nourishment, through the primary membrane. In like manner, the ultimate follicles

and tubuli of the glands are surrounded by a copious network of capillaries (Fig. 10); and it is from these, through the primary membrane, that the cells of these follicles draw their nourishment. Hence this membrane, in every instance, forms a complete septum, on the one hand between the stream of blood in the vessels and the surrounding tissues, since it forms the lining even of the minutest capillaries; and on the other between the fluids in the interstices of the substance of the true skin, the mucous membranes, &c., and the cells covering their free surfaces. It is evident, therefore, that whilst bounding these tissues and restraining the too free passage of fluids from their surfaces, it allows the transudation of a sufficient amount for the nutrition of the cells which lie upon it; and, as we shall presently see, these cells frequently pass through all their stages of growth so rapidly, that a very free supply of nutriment must be required by them. Hence, notwithstanding its apparent homogeneousness, the primary membrane must have a structure which readily admits the passage of fluid. In this respect it corresponds with the membrane, which forms the wall of the *cells* of both Animal and Vegetable tissues; for this also appears completely homogeneous and structureless, when seen under its simplest aspect, and yet allows the free passage of fluids from one cell to another.

208. But it is probable that this membrane performs a much more important office than that of simply limiting the fluids, whilst allowing the requisite transudation. We cannot account for the new production of cells, which (as will presently appear) is continually taking place on its surface, without referring to it as the originator of these cells,—that is, as the source of their germs. The new generations of cells cannot here be developed by the reproductive powers of the old ones (§ 211); since the latter are often completely cast off entire, before they can liberate the reproductive granules; or they undergo changes which evidently unfit them for such a purpose. Thus in the Epidermis we shall find that they become flattened into dry scales, forming an almost horny layer on the surface of the body; whilst the new cells are originating beneath, from the surface of the basement-membrane (§ 224 and Fig. 16). Hence we cannot find any other origin for these cells than in the basement-membrane itself; and there seems every probability that the granules, which have been mentioned as being frequently diffused through it, are in reality the germs of cells to be developed from its surface; whilst the distinct spots are collections of similar granules, each of which may give origin to a large number of such cells, which spring from them as from a centre. We shall presently see that these "germinal centres" closely resemble the *nuclei* of cells in general, from which it is unquestionable that new crops of cells may arise (§ 250). The only difference is, that in the latter case, the groups of new cells are for a time contained within the parent-cell (Fig. 30); whilst

Fig. 13.



Component cells of primary membrane, with adherent epithelial cells.

in the former, they are developed on the free surface of the basement membrane. In Fig. 13 is shown a portion of the same membrane as that represented in Fig. 12; but having been rendered transparent by acetic acid, its real nature as a layer of flattened nucleated cells is more obvious; the nucleus or germinal spot of the central cell has given origin to a cluster of oval epithelial cells, of which five still adhere to it.

209. Hence we are probably to regard this primary or basement membrane as *transitional*, rather than a *permanent* structure; and to look upon it as furnishing the germs of all the cells, which are developed upon its surface; as well as the medium, through which they are supplied with nutriment. It must be continually undergoing *disintegration*, therefore, on its *free* surface; and must be as continually renewed, at the side in relation with the blood-vessels.

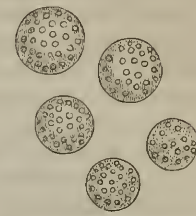
4. *Of Simple Isolated Cells, employed in the Organic Functions.*

210. The active functions of the Animal body are performed, to a much greater extent than was until lately believed, by the agency of *simple isolated cells;* of which every one grows and lives quite independently of the rest, just as if it were one of the simplest cellular plants (§ 30); but of which all are dependent upon the general nutritive fluid for the materials of their development, imbibing it from the currents that circulate in their neighbourhood. It may be said, indeed, that *all* the Vegetative functions of the body,—all the processes of Nutrition and Reproduction,—all those operations, in short, which are common to Plants and Animals,—are performed in the Animal and Vegetable structures by the very same means, the agency of cells; and this is true, not only of the healthy actions, but of various morbid operations, in which the unusual development of cells, possessing peculiar endowments, performs a most conspicuous part. Hence it will be necessary to enter somewhat at large into the history of cell-development in the Animal body; and the various modifications under which this process may take place. In fact, a knowledge of the Physiology of Cells may be regarded as the foundation of all accurate acquaintance with that department of the Science, which relates to the Nutritive and Reproductive processes; and it has a considerable bearing, as we shall see hereafter, upon the history of the purely Animal functions.

211. The history of the Animal cell, in its simplest form, is precisely that of the Vegetable cell of the lowest kind. It lives *for* itself and *by* itself; and is dependent upon nothing but a due supply of nutriment, and of the appropriate stimuli, for the continuance of its growth and for the due performance of all its functions, until its term of life is expired. It originates from a reproductive granule, previously formed by some other cell; this granule attracts to itself, assimilates, and organizes, the particles of the nutrient fluid in its neighbourhood; converts some of them into the substance of the

cell-wall, whilst it draws others into the cavity of the cell; in this manner the cell gradually increases in size; and whilst it is itself approaching the term of its life, it usually makes preparation for its renewal, by the development of reproductive granules in its interior, which may become the germs of new cells, when set free from the cavity of the parent. There is an important difference, however, in the endowments of the Animal and Vegetable cell. We have seen that the latter can in general obtain its nutriment, and the materials for its secretion, by itself combining the inorganic elements into organic compounds. The former, however, is totally destitute of this power; it can *produce* no organic compound, and we have yet to learn how far its power of *transforming* one compound into another may extend; and its chief endowment seems to be that of attracting or drawing to itself some of the various substances, which are contained in the nutritive fluid in relation with it. This fluid, as we shall see hereafter, is a mixture of a great number of compounds; and different sets of cells appear destined severally to appropriate these, just as the different cells of a parti-coloured flower have the power of drawing to themselves the elements of their several colouring matters. As far as is yet known, however, the composition of the *cell-wall* is everywhere the same; being that of Proteine. It is in the nature of the *contents* of the cell, that (as among the cells of Plants) the greatest diversity exists; and we shall find that the *purposes* of the different groups of cells, in the Animal economy, depend upon the nature of the products they secrete, and upon the mode in which these products are given back after they have been subjected to the action of the cells.

Fig. 14.



Simple isolated cells, containing reproductive molecules.

212. The very simplest and most independent condition of the Animal Cell is probably to be found in the Blood, the Chyle, and the Lymph; in all of which liquids we meet with floating cells, which are completely isolated from one another, and which are consequently just as independent as the vesicles of the Red Snow or other simple cellular Plants. Indeed in the nature of their *habitat*, we may compare them with the Yeast-Plant; for as this will only vegetate in a saccharine fluid containing vegetable albumen, so do we find that these floating cells will only grow and multiply in the albuminous fluids of animals. In their general appearance they very closely correspond with the figure already given as the *type* of the simple cell. Their diameter is pretty uniform in the different fluids of the body, and even in different animals; being for the most part about 1-3000th of an inch. They are sometimes nearly spherical, and sometimes flattened; when they present the latter shape, they may be made to swell out into the spherical form (see *Frontispiece*, Figs. 4 and 5), by the action of water, which they imbibe according to the laws of Endosmose,—the thinner fluid, water, passing towards the more viscid

contents of the cell, and mingling with them. By the continuance of this kind of action, the cell will be caused to burst. These cells, which are known as the corpuscles of the Chyle and Lymph, and as the *White* Corpuscles of the Blood, are observed to contain a number of minute molecules in their interior (*Front.* Fig. 4); and at a certain stage of their development,—probably that which immediately precedes the maturation and rupture of the parent-cell,—these molecules may be seen, with a good Microscope, in active movement within the cavity. The action of a very dilute solution of potash causes the immediate rupture of these cells, and the discharge of the contained molecules, which are probably the germs of new cells of a similar character. And when they rupture spontaneously, which they are much disposed to do under the influence of contact with air, the fluid which they set free shows an obvious tendency to assume a fibrous arrangement.

213. There is reason to think that these cells have for their office the transformation of Albumen into Fibrin; that is to say, the elaboration of the spontaneously-coagulating and fibrillating substance, from the mere chemical compound which forms the raw material of the Animal tissues. For we find these cells in every situation in which we know the transformation to be going on; and we observe their number to bear a close relation with the amount of fibrin produced in the fluid. Thus in the Inflammatory process, the quantity of fibrin in the blood is very greatly augmented; and the number of white corpuscles found in that fluid, when it is drawn from the body, is very largely increased. Moreover they are observed to accumulate in great numbers in the vessels of inflamed parts; and not only in these, but in all parts where processes of growth and reparation are going on, which require a large supply of highly-elaborated fibrin. They are found, too, in the exudations of fibrinous matter, poured out from the blood upon wounded or inflamed surfaces; and here they show the very same properties as the white or colourless corpuscles of the blood,—that is, they exhibit moving molecules in their interior; they burst and emit these when brought in contact with an alkaline solution; and their fluid contents show a disposition to fibrillate, when they are not altered by any chemical reagent. Hence it may be concluded that they belong to the same class of cells; being probably developed from granular germs set free from the blood, along with the matter of the fibrinous exudation itself.

Fig. 15.

Colourless cells, with active molecules, and fibres of fibrin, from Herpes labialis.

214. The history of the simple Animal cell corresponds, therefore, in all essential particulars with that which has been already described as the simplest form of Life or Vital Activity; but we now see how the separate life of the individual cells is made to contribute to the general life of the entire organism,

and is at the same time dependent upon it. If the nutrient material were not prepared by other processes, these cells could not exist; on the other hand, if this nutrient material were not further elaborated by *their* action, no subsequent processes of growth could take place. The compounds which are formed as products of secretion in the simple Vegetable cell, are given back to the external world from which their materials were drawn, when that cell ceases to exist; to be used, perhaps, in the general economy of nature, as the material for some *other* and higher structure. But when such cells themselves form a portion of a higher and more complex fabric, whether of the Plant or Animal, the substances they yield back as the products of their action, are made use of in some other set of processes in the economy of the same being. Thus the fibrin-elaborating cells, of which we have been speaking, appear to be continually growing, dying, and reproducing themselves; drawing albumen from the fluid in which they float, and returning it as fibrin, to supply the constant drain of that substance, which is occasioned by the nutritive operations.

215. Besides the cells already mentioned, the blood of Vertebrated animals also contains others, which are distinguished by their *red* colour and flattened form. These are equally isolated, and lead an independent life; undergoing all their changes whilst floating in the rapidly-circulating current. These Red Corpuscles are found but very sparingly in the blood of invertebrated animals; and only in that of the higher classes. Their proportion in the blood of Vertebrata varies considerably in the several groups of that sub-kingdom; and seems to be closely connected with the relative activity of respiration in each case. They present, in every instance, the form of a flattened disk, which is circular in Man and in most Mammalia (*Front.* Fig. 1), but which is oval in Birds, Reptiles, and Fishes, and in a few Mammals (*Front.* Fig. 6). This disk is in both instances a flattened cell, whose walls are pellucid and colourless, but whose contents are coloured. Like the corpuscles already described, they may be caused to swell up and burst, by the imbibition of water; and the perfect transparency and the homogeneous character of their walls then become evident. (*Front.* Fig. 8, *e.*) These red corpuscles are not only distinguished from the others by the colour of their contents; they are also characterized by the absence of the separate molecules, which formed so distinctive a feature in the preceding; and in Oviparous Vertebrata by the presence of a distinct central spot or *nucleus*. This nucleus appears to be composed of an aggregation of minute granules, analogous to those which are elsewhere diffused through the interior of the cell; and it is undoubtedly the source from which new cells may originate within the parent, as will be presently explained. The nucleus (where it exists) may be easily obtained separate from the cell-wall and its contents, by treating the red corpuscles with water. The first effect of this is to render the nucleus rather more distinct, as is seen by contrasting the corpuscle which has been thus slightly acted

on (*Front.* Fig. 8, *a*), with the unaltered corpuscle (*Front.* Fig. 6) of the same animal. After a short time, the corpuscle swells out and becomes more circular (*Front.* Fig. 8, *b*); and in a short time longer, the nucleus is seen, not in the centre of the disk, but near its margin (*Front.* Fig. 8, *c*, *d*). Finally, the wall of the cell ruptures; the nucleus and its other contents are set free; and whilst the colouring matter is diffused through the surrounding fluid, the cell-walls and the nuclei are separately distinguishable. (*Front.* Fig. 8, *e*.)

216. It is remarkable, however, that the red corpuscles of the blood of Mammals should possess no obvious nucleus; the dark spot which is seen in their centre (*Front.* Fig. 1), being merely an effect of refraction in consequence of the double-concave form of the disk. When the corpuscles are treated with water, so that their form becomes first flat, and then double-convex, the dark spot disappears; whilst, on the other hand, it is made more evident when the concavity is increased by the partial emptying of the cell, which may be accomplished by treating the blood-corpuscles with fluids of *greater* density than their own contents. Observers are much divided upon the question, whether or not the blood-disks of Mammals really contain a nucleus. There seems every probability, from analogy, that a nucleus exists in them as in all other red corpuscles; but it cannot be brought into view by any ordinary method. Dr. G. O. Rees states, however, that by carefully examining the deposit at the bottom of water through which red corpuscles had been diffused, he could distinguish appearances that indicated the existence of nuclei; although they escape observation when within the corpuscles themselves, on account of their high refractive power. He describes them as being circular and flattened like the red corpuscles themselves; and about two-thirds their diameter.

217. The size of the Red Corpuscles is not altogether uniform in the same blood; thus it varies in that of Man from about the 1-4000th to the 1-2800th of an inch. But we generally find that there is an average size, which is pretty constantly maintained among the different individuals of the same species; that of Man may be stated at about 1-3400th of an inch. The round corpuscles of the Mammalia do not in general depart very widely from this standard; except in the case of the Musk-Deer, in which they are less than 1-12000th of an inch in diameter. It is in the Camel tribe alone that we find oval corpuscles among Mammals: these have about the same average length as the round corpuscles of Man, but little more than half the breadth.—In Birds, the corpuscles are occasionally almost circular; but in general their diameters are to each other as $1\frac{1}{2}$ or 2 to 1. The size of the corpuscles is usually greater according to the size of the Bird; thus among the Ostrich tribe, the long diameter is about 1-1650th of an inch, and the short diameter 1-3000th; whilst among the small Sparrows, Finches, &c., the long diameter is about 1-2400th, and the short frequently does not exceed half that amount.

218. It is in Reptiles that we find the largest red corpuscles; and

it is in their blood, therefore, that we can best study the characters of these bodies. The blood-discs of the Frog, from the facility with which they may be obtained, are particularly suitable for the purpose; their long diameter is about the 1-1000th of an inch, whilst their short or transverse diameter is about 1-1800th. The curious Proteus, Siren, and other allied species, which retain their gills through their whole lives, are distinguished by the enormous size of their blood-disks. The long diameter of the corpuscles of the Proteus is about 1-337th of an inch; they are consequently almost distinguishable with the unaided eye. The long diameter of the corpuscles of the Siren is about 1-435th of an inch, and their short diameter about 1-800th; the long diameter of the nuclei of these corpuscles is about 1-1000th, and the short diameter about 1-2000th of an inch,—so that the nuclei are about three times as long, and nearly twice as broad as the entire human corpuscles.

219. There can be little doubt that the Red Corpuscles go through the same history as other cells; and there is evidence that they are rapidly regenerated, under favourable circumstances, when a large number of them have been lost. When much blood has been drawn from the body, the proportion of red corpuscles in the remaining fluid is at first considerably lowered: since the fluid portion of the blood is replaced almost immediately, whilst these floating cells require time for their regeneration. Their amount progressively increases, however, until it has reached its proper standard, provided that a due supply of the materials be afforded. We shall presently see that one of these materials is Iron; and it is well known that iron administered internally is an important aid in recovery from severe hemorrhages, as well as a valuable remedy for certain constitutional states, in which there is a diminished power of producing red corpuscles. Thus in Chlorosis, under the administration of iron, the amount of red corpuscles in the blood has been doubled within a short period. Hence there can be no doubt that the Red Corpuscles are produced from germs, and grow like other cells, under circumstances favourable to their development; and it is probable that, in the healthy state of the system, the constant production, and the constant death and disintegration, balance one another. In some instances (as in Chlorosis) the production is not sufficient to make up for the loss by death; and the total amount in the blood undergoes an extraordinary diminution, sometimes even to less than a quarter of their proper proportion. In other cases, under the influence of excessive nutriment (as in the state termed Plethora), the proportion of Red Corpuscles is increased beyond the normal amount; and in this condition, the loss of a small quantity of blood may be a preservative from the evils to which it is incident, from Hemorrhage of various kinds.

220. The precise mode in which the Red Corpuscles are usually developed, has not yet been positively determined; and there is still a degree of uncertainty with respect to their parentage,—in other words, as to the source of their primitive germs. In the fluid withdrawn from

the heart of the embryo chick about the third day, the whole process of the formation of the oval red corpuscles from minute granules has been distinctly traced; and there is every probability that these granules are cell-germs set free by some of the cells of the primary embryonic structures, which thus originate blood-corpuscles, in the same manner as other cells originate bone, nerve, muscle, &c. The subsequent increase and constant maintenance of the number of red corpuscles, can scarcely be due to any other process, than that by which similar isolated cells are regenerated; that is, by the continual production of new generations by germs prepared by the parent. According to the celebrated Leeuwenhoek, certain red corpuscles are occasionally seen to divide themselves into six, which, at first very small, gradually increase to the size of their parents; and this observation has been confirmed by Dr. Barry, who regards the multiplication as due to the development of six young cells, which sprout from the circumference of the nucleus, and grow at first within the cell-wall of the parent, but afterwards rupture it, and become free. On the other hand, Dr. G. O. Rees affirms, that, when examining a portion of blood maintained at about its natural temperature, he observed some of the corpuscles to assume an hour-glass form, by a contraction across their middle; and that, by the increase of this contraction, producing the division of the corpuscles, two unequal-sized circular bodies were eventually produced from each; which, when treated with a strong saline solution, were emptied of their contents, like ordinary blood-disks. It can scarcely be doubted that, in one of these modes, the Red corpuscles reproduce themselves; and that in this manner a continual succession is kept up. Some have supposed that the *Red* corpuscles originated from the *White* or colourless corpuscles previously described; but this idea seems to have little other foundation, than the correspondence in size between the colourless corpuscles of the Frog's blood, and the nuclei of its red corpuscles. This correspondence is quite accidental, however; for in Man, the colourless corpuscles are somewhat larger than the entire red disks; in the Musk-deer, they are far larger; and in the Proteus they are far smaller than the nuclei of the latter. For the diameter of the Colourless corpuscle varies extremely little; whilst that of the red, as we have seen, has a range from 1-337th of an inch to less than 1-12,000th.

221. The Chemical composition of the walls and nuclei of the Red corpuscles is very different from that of their contents. The substance of the former has been termed *Globuline;* but it does not seem to differ in any essential character from other substances resulting from the organization of the proteine-compounds. The compound which forms the contents of the red corpuscles, however, and gives them their characteristic hue, is altogether peculiar, and has received the name of *Hæmatine.* Its composition is notably different from that of the proteine-compounds; the proportion of Carbon to the other ingredients being very much greater; and a definite quantity of iron being

an essential part of it. Its formula is 44 Carbon, 22 Hydrogen, 3 Nitrogen, 6 Oxygen, and 1 Iron. When completely separated from albuminous matter, it is a dark brown substance, incapable of coagulation, nearly insoluble in water, alcohol, ether, acids, or alkalies, alone; but readily soluble in alcohol mixed either with sulphuric acid or ammonia. The solution, even when diluted, has a dark colour; and possesses all the properties of the colouring matter of venous blood. The iron may be separated from the hæmatine by strong reagents which combine with the former, and the latter still possesses its characteristic colour. This hue cannot be dependent, therefore, on the presence of iron in the state of peroxide; as some have supposed. On the other hand, the iron is most certainly united firmly with the ingredients of the hæmatine, as contained in the red corpuscles; for this may be digested in dilute sulphuric or muriatic acid for many days, without the least diminution in the quantity of iron, the usual amount of which may be afterwards obtained by combustion from the hæmatine that has been subjected to this treatment. This experiment seems further to prove, that the iron cannot be united with the hæmatine in the state of either protoxide or peroxide, as maintained by Liebig; since weak acids would then dissolve it out.

222. Regarding the nature of this compound, and the changes which it undergoes in respiration, there is still much to be learned; and until these points have been more fully elucidated, the precise uses of the red corpuscles in the animal economy cannot be understood. There is evidence, however, that the production of Hæmatine is (like the production of the red colouring matter of the Protococcus nivalis, § 31), a result of chemical action taking place in the cells themselves; for no substance resembling Hæmatine can be found in the liquid in which these cells float, and scarcely a trace of iron can be detected in it; whilst, on the other hand, the fluid portion of the chyle holds a large quantity of iron in solution, which seems to be drawn into the red corpuscles, and united with the other constituents of hæmatine, as soon as ever it is delivered into the circulating current. The colouring matter appears to exist in two states, the precise chemical difference between which has not yet been ascertained. In arterial blood it is a florid scarlet; whilst in venous blood it is of a purpler hue. By circulating through the capillaries of the system, the arterial or bright hæmatine becomes converted into dark or venous hæmatine; and the converse change takes place in the capillaries of the lungs, the original florid hue being recovered. Now it is certain that the blood, in its change from the arterial to the venous condition, loses oxygen, and becomes charged with an increased amount of carbonic acid, although its precise mode of combination is not known; on the other hand, in its return from the venous to the arterial state, the blood gives off this additional charge of carbonic acid, and imbibes oxygen. The change of colour, under similar conditions, takes place out of the body, as well as in it. Thus if venous blood be exposed for a short time to the air, its *surface*

becomes florid; and the non-extension of this change to the interior of the mass is evidently due to the impossibility of bringing air into relation with every particle of the blood, in the manner in which the lungs are so admirably contrived to effect. If venous blood be exposed to pure oxygen, the change of colour will take place still more speedily; and it is not prevented by the interposition of a thick animal membrane, such as a bladder, between the blood and the gas. On the other hand, if arterial blood be exposed to carbonic acid, it loses its brilliant hue, and is rendered as dark as venous blood; or even darker, if exposed very completely to its influence. The simple removal of this carbonic acid is not sufficient to restore the original colour; for this removal may be effected by hydrogen, which has the power of dissolving out (so to speak) the carbonic acid diffused through the blood, without the restoration of the arterial hue, unless oxygen be present, or saline matter be added to the blood.

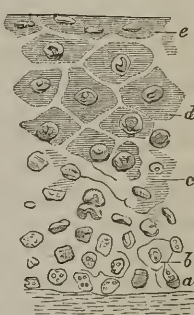
223. These changes in the condition of the contents of the Red corpuscles, taken in connection with the fact, that these bodies are almost completely restricted to the blood of Vertebrata, (whose respiration is much more energetic than that of any Invertebrated animals save Insects, which have a special provision of a different character,) and that their proportion to the whole mass of the blood corresponds with the activity of the respiratory function,—leave little doubt that they are actively (but not exclusively) concerned as *carriers* of Oxygen from the lungs to the tissues, and of Carbonic acid from the tissues to the lungs; and that they have no other direct concern in the functions of Nutrition, than the fulfilment of this duty. Their complete absence in the lower Invertebrated animals, in the earliest condition of the higher, and in newly-forming parts until these are penetrated by blood-vessels, seems to indicate that they have no immediate connection with even the most energetic operations of growth and development; whilst, on the other hand, there is abundant evidence, that the normal activity of the *animal* functions is mainly dependent upon their presence in the blood in due proportion.

224. Next in independence to the cells or corpuscles floating in the animal fluids, are those which cover the free membranous surfaces of the body, and form the *Epidermis* and *Epithelium*. Between these two structures there is no more real difference, than there is between the Skin and the Mucous membranes. The one is continuous with the other; they are both formed of the same elements; they are cast off and renewed in the same manner; the history of the life of the individual cells of each is nearly identical; but there is an important difference in the purposes, which they respectively serve in the general economy. The *Epidermis* or Cuticle covers the exterior surfaces of the body, as a thin semi-transparent pellicle, which is apparently homogeneous in its texture, is not traversed by vessels or nerves, and was formerly supposed to be an inorganic exudation from the surface of the true Skin, designed for its protection. It is now known, however, to consist of a series of layers of cells, which are continually

wearing off at the external surface, and are being renewed at the surface of the true skin; so that the newest and deepest layers gradually become the oldest and most superficial, and are at last thrown off by slow desquamation. Occasionally this desquamation of the cuticle is much more rapid; as after Scarlatina and other inflammatory affections of the Skin.

225. In their progress from the internal to the external surface of the Epidermis, the cells undergo a series of well-marked changes. When we examine the innermost layer, we find it soft and granular; consisting of *nuclei*, in various stages of development into cells, held together by a tenacious semi-fluid substance. This was formerly considered as a distinct tissue, and was supposed to be the peculiar seat of the colour of the skin; it received the designation of *rete mucosum.* Passing outwards, we find the cells more completely formed; at first nearly spherical in shape; but becoming polygonal where they are flattened against one another. As we proceed further towards the surface, we perceive that the cells are gradually more and more flattened, until they become mere horny scales, their cavity being obliterated; their origin is indicated, however, by the nucleus in the centre of each. This flattening appears to result from the gradual desiccation or drying-up of the contents of the cells, which results from their exposure to the air. Thus each cell of the Epidermis is developed from the nucleus on the surface of the basement membrane, (which nucleus is probably furnished by the membrane itself, § 208,) and is gradually brought to the surface by the development of new cells beneath, and the removal of the superficial layers; whilst at the same time it is progressively changed in form, until it is converted into a flattened scale. The accompanying representation of an oblique section of the Epidermis, exhibits the principal gradations of its component structures.

Fig. 16.

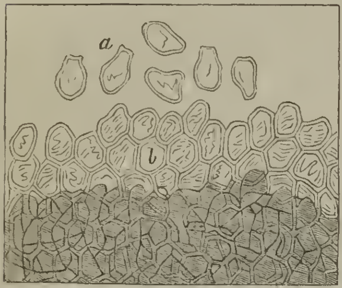


Oblique section of Epidermis, showing the progressive development of its component cells;—*a*, nuclei, resting upon the surface of the cutis vera *f*; these nuclei are seen to be gradually developed into cells, at *b*, *c*, and *d*; and the cells are flattened into lamellæ, forming the exterior portion of the epidermis at *e*.

226. The Epidermis covers the whole exterior surface of the body; not excepting the Conjunctiva of the eye, on which, however, it has more the character of an Epithelium; and the Cornea, on which it participates in the horny character of the Epidermic covering of the skin. The continuity is well seen in the cast skin or *slough* of the Snake; in which the covering of the front of the eye is found to be as perfectly exuviated, as that of any part of the body. The number of layers varies greatly in different parts; being usually found to be the greatest, where there is most pressure or friction. Thus on the soles of the feet, particularly at the heel and the ball of the great toe, the Epidermis is extremely thick; and the palms of the hands of the labouring

man are distinguished by the increased density of their horny covering. It would seem as if the irritation of the Skin stimulated it to an increased production of this substance. The Epidermic membrane is pierced by the excretory ducts of the sweat glands, and of the sebaceous follicles, which lie in the true skin and immediately beneath it; or we should rather say that it is continuous with the delicate epithelial lining of these.—The *Nails* may be considered as nothing more than an altered form of Epidermis. When examined near their origin, they are found to consist of cells which gradually dry into scales; and these remain coherent together. A new production is continually taking place in the groove of the skin, in which the root of the nail is imbedded; and probably also from the whole subjacent surface.

Fig. 17.



Horny Epidermis, from conjunctiva covering the cornea; *a*, single scales; *b*, simple lamina of epithelium; below is seen a double layer of the same.

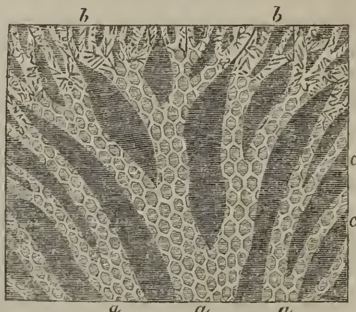
227. The Epidermis, when analyzed, is found to differ from the proteine-compounds in its composition; but not in any very striking degree. The proportion of its elements is considered to be 48 Carbon, 39 Hydrogen, 7 Nitrogen, 17 Oxygen; and this corresponds exactly with the composition of the substance of which Nails, Horn, Hair and Wool are constituted. It seems probable, however, that the *cell-walls* are formed, as elsewhere, of Fibrin; and that the horny matter is a secretion in their interior, which is drawn from the elements of blood during their growth and development.

228. The Epidermis appears solely destined for the *protection* of the true Skin; both from the mechanical injury and the pain, which the slightest abrasion would produce; and from the irritating effects of exposure to the external air, and of changes of temperature. We perceive the value of this protection, when the Epidermis has been accidentally removed. It is very speedily replaced, however; the increased determination of blood to the Skin, which is the consequence of the irritation, being favourable to the rapid production of Epidermic cells on its surface.

229. Mingled with the Epidermic cells, we find others which secrete colouring matter instead of horn; these are termed *Pigment-cells*. They are not readily distinguishable in the epidermis of the White races, except in certain parts, such as the areola around the nipple, and in freckles, nævi, &c. But they are very obvious, on account of their dark hue, in the newer layers of the Epidermis of the Negro and other coloured races; and, like the true Epidermic cells, they dry up and become flattened scales in their passage towards the surface, thus constantly remaining dispersed through the Epidermis, and giving it a dark tint when it is separated and held up to the light.

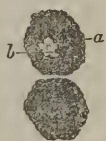
In all races of men, however, we find the most remarkable development of Pigment-cells on the inner surface of the Choroid coat of the eye, where they form several layers, known as the *Pigmentum nigrum*. Here they have a very regular arrangement, which is best seen where they cover the blood-vessels of the Choroid coat in a single layer, as shown in Fig. 18. When examined separately, they are found to have a polygonal form (Fig. 19, *a*), and to have a distinct nucleus (*b*) in their interior. The black colour is given by the accumulation, within the cell, of a number of flat, rounded or oval granules, measuring about 1-20,000th of an inch in diameter, and a quarter as much in thickness; these, when separately viewed, are observed to be transparent, not black and opaque; and they exhibit an active movement when set free from the cell, and even whilst enclosed within it. The pigment-cells are not always of a simple rounded or polygonal form; they sometimes present remarkable stellate prolongations, under which form they are well seen in the skin of the Frog.—The Chemical nature of the black pigment has not yet been made evident; it has been shown, however, to have a close relation with that of the Cuttle-fish ink or Sepia, which derives its colour from the pigment-cells lining the ink-bag; and to include a larger proportion of Carbon than most other organic substances,—every 100 parts containing 58½ of this element.

Fig. 18.



A portion of the choroid coat from the eye of the Ox, showing the pigment-cells, where they cover *a*, *a*, *a*, the veins, in a single layer; *b*, *b*, ramifications of the veins near the ciliary ligament, covered with less regular pigment-cells; *c*, *c*, spaces between the vessels, more thickly covered with pigment-cells.

Fig. 19.



Corpuscles of Pigment, magnified 300 diameters;—*a*, cell; *b*, nucleus.

230. That the development of the Pigment-cells, or at least the formation of their peculiar secretion, is in some degree due to the influence of Light, seems evident from the facts already mentioned (§ 93). To these it may be added, that the new-born infants of the Negro and other dark races do not exhibit nearly the same depth of colour in their skins, as that which they present after the lapse of a few days; which seems to indicate that exposure to light is necessary for the full development of the characteristic hue. An occasional development of dark pigment-cells takes place during pregnancy in some females of the fair races; thus it is very common to meet with an extremely dark and broad areola round the nipple of pregnant women; and sometimes large patches of the cutaneous surface, on the lower part of the body especially, become almost as dark as the skin of the Negro. On the other hand, individuals are occasionally seen

with an entire deficiency of pigment-cells, or at least of their proper secretion, not merely in the skin, but in the eye; such are termed Albinoes; and they are met with as well among the fair, as among the dark races. The absence of colour usually shows itself also in the hair, which is almost white.

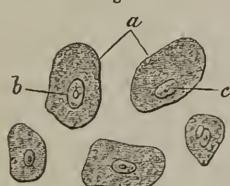
231. The *Epithelium* may be designated as a delicate cuticle, covering the free *internal* surfaces of the body; and apparently designed, in some instances, simply for their protection; whilst in other cases, as we shall presently find, it serves purposes of far greater importance. It has long been known that the Epidermis might be traced continuously from the lips to the mucous membrane of the mouth, and thence down the œsophagus into the stomach; and that in the strong muscular stomach or gizzard of the granivorous birds, it becomes quite a firm horny lining. But it has been only ascertained by the use of the Microscope, that a continuous layer of cells may be traced, not merely along the whole surface of the mucous membrane lining the alimentary canal, but likewise along the free surfaces of all other Mucous membranes, with their prolongations into follicles and glands; as well as on Serous and Synovial membranes, and the lining membrane of the heart, blood-vessels, and absorbents. The Epithelial cells, being always in contact with fluids, do not dry up into scales like those of the Epidermis; and they differ from them also in regard to the nature of the matter, which they secrete in their interior. In this respect, however, the Epithelial cells of different parts are unlike one another, fully as much as any of them are unlike the cells of the Epidermis; for we shall find that *all* the secretions of the body are the product of the elaboration of Epithelium cells; and consequently there are as many varieties of endowment, in these important bodies, as there are varieties in the result of their action.

232. The Epithelium covering the Serous and Synovial membranes, and the lining of the blood-vessels, is composed of flattened polygonal cells, (resembling those shown in Fig. 20,) lying in apposition with each other, so as to form a kind of pavement; hence this form is termed *pavement* or *tesselated*-Epithelium. There is no reason to believe that it possesses any active endowments in these situations; since it does not appear to be concerned in the elaboration of any peculiar secretion. It has been already pointed out (§ 196), that the fluid of serous membranes is separated from the blood by a simple act of mechanical transudation, (which often takes place to a great extent after death;) the walls of the blood-vessels do not appear to be concerned in forming any peculiar secretion; and the only product of this kind, which indicates any special endowment in the epithelium-cells, is the synovia, which is probably elaborated by the cells covering the vascular fringes of the synovial membrane, formerly mentioned (§ 197). The cells draw it from the blood, during the progress of their growth, form it as a secretion within themselves, and then cast it into the general cavity of the joint, (when their term of individual life is ended,) either by the rupture or the liquefaction of their walls.

In other cases, it would seem as if the epithelial cells were not frequently cast off and renewed, but possessed a considerable permanency. It is to be remembered that, in the healthy state of the serous and synovial membranes, and in that of the lining membrane of the blood-vessels and absorbents, they are entirely secluded from sources of irritation; and that they lead a sort of *passive* life, very different from the *active* life of the mucous membranes. In fact, it would appear to be the sole object of the serous membranes, to enclose and suspend the viscera, in such a manner as to allow of the access of blood-vessels, nerves, gland-ducts, &c.; and at the same time to permit them the required freedom of motion, and to provide against the irritation of opposing parts, by furnishing an extremely smooth and moistened surface, wherever friction takes place. Hence we find membranes, with all the characters of serous surfaces, in the false joints formed by ununited fractures, and in other similar situations.

233. The Epithelium of the Mucous membranes and their prolongations is found under two principal forms, the *tesselated*, and the *cylindrical*. An example of the Tesselated form is shown in Fig. 20,

Fig. 20.



Separated Epithelium-cells, *a*, with nuclei, *b*, and nucleoli, *c*, from mucous membrane of mouth.

Fig. 21.

Pavement-Epithelium of the Mucous Membrane of the smaller bronchial tubes; *a*, nuclei with double nucleoli.

which shows the separate epithelium-cells of the mucous membrane of the mouth, as they are frequently met with in saliva. The cells are not always so polygonal in form, however; sometimes retaining their rounded or oval form, and being separated by considerable interstices, so that they can scarcely be said to form a continuous layer. A specimen of this kind is seen in Fig. 21, which represents a group of epithelium-cells from one of the smaller bronchial tubes. This form of tesselated epithelium is more commonly met with, where the secreting operations are more active, the life of the cells consequently shorter, and the renewal of them more frequent; so that they have not time, so to speak, to be developed into a more continuous layer.—The Cylinder-Epithelium is very differently constituted. Its component cell are cylinders, which are arranged side by side; one extremity of each cylinder resting upon the basement-membrane, whilst the other forms part of the free surface. The perfect cylindrical form is only shown, when the surface on which the cylinders rest is flat or nearly so. When it is *convex*, the lower ends or base-

ments of the cells are of much smaller diameter than the upper or free extremities; and thus each has the form of a truncated cone, rather than of a cylinder. (Fig. 22.) This is well seen in the cells which cóver the *villi* of the intestinal canal. (Fig. 28.) On the other hand, where the cylinder-epithelium lies upon a *concave* surface, the free extremities of the cells may be smaller than those which are attached. Sometimes each cylinder is formed from more than one cell, as is shown by the nuclei it contains; although its cavity seems to be continuous from end to end. And occasionally the cylinders arise by stalk-like prolongations, from a tesselated epithelium beneath. The two forms of Epithelium pass into one another at various points; and various transitional forms are then seen,—the tesselated scales appearing to rise more and more from the surface, until they project as long-stalked cells, truncated cones, or cylinders.

234. Both these principal forms of Epithelial cells are frequently observed to be fringed at their free margins with delicate filaments, which are termed *cilia;* and these, although of extreme minuteness, are organs of great importance in the animal economy, through the extraordinary motor powers with which they are endowed. The form of the ciliary filaments is usually a little flattened, and tapering gradually from the base to the point. Their size is extremely variable; the largest that have been observed being about 1-500th of an inch in length, and the smallest about 1-13,000th. When in motion, each filament appears to bend from its root to its point, returning again to its original state, like the stalks of corn when depressed by the wind; and when a number are affected in succession with this motion, the appearance of progressive waves following one another is produced, as when a corn-field is agitated by frequent gusts. When the ciliary motion is taking place in full activity, however, nothing whatever can be distinguished, but the whirl of particles in the surrounding fluid; and it is only when the rate of movement slackens, that the shape and size of the cilia, and the manner in which their stroke is made, can be clearly seen. The motion of the cilia is not only quite independent (in all the higher animals at least) of the will of the animal, but is also independent even of the life of the rest of the body; being seen after the death of the animal, and proceeding with perfect regularity in parts separated from the body. Thus isolated epithelium-cells have been seen to swim about actively in water, by the agency of their cilia, for some hours after they have been detached from the mucous surface of the nose; and the ciliary movement has been seen fifteen days after death in the body of a Tortoise, in which putrefaction was far advanced. In the gills of the River-Mussel, which are among the

Fig. 22.

Vibratile or ciliated Epithelium;—*a*, nucleated cells, resting on their smaller extremities; *b*, cilia.

best objects for the study of it, the movement endures with similar pertinacity.

235. The purpose of this ciliary movement is obviously to propel fluids over the surface on which it takes place; and it is consequently limited in the higher animals to the internal surfaces of the body, and always takes place in the direction of the outlets, towards which it aids in propelling the various products of secretion. The case is different, however, among animals of the lower classes, especially those inhabiting the water. Thus the external surface of the gills of Fishes, Tadpoles, &c., is furnished with cilia; the continual movement of which renews the water in contact with them, and thus promotes the aëration of the blood. In the lower Mollusca, and in many Zoophytes, which pass their lives rooted to one spot, the motion of the cilia serves not merely to produce currents for respiration, but likewise to draw into the mouth the minute particles that serve as food. And in the free-moving Animalcules, of various kinds, the cilia are the sole instruments which they possess, not merely for producing those currents in the water which may bring them the requisite supply of air and food, but also for propelling their own bodies through the water. This is the case, too, with many larger animals of the class Acalepha (Jelly-fish), which move through the water, sometimes with great activity, by the combined action of the vast numbers of cilia that clothe the margins of their external surfaces. In these latter cases it would seem as if the ciliary movement were more under the control of the will of the animal, than it is where it is concerned only in the organic functions. In what way the will can influence it, however, it does not seem easy to say; since the ciliated epithelium-cells appear to be perfectly disconnected from the surface on which they lie, and cannot, therefore, receive any direct influence from their nerves. Of the cause of the movement of the cilia themselves, no account can be given; they are usually far too small to contain even the minutest fibrillæ of muscle; and we must regard them as being, like those fibrillæ, organs *sui generis*, having their own peculiar endowment,—which is, in the higher animals at least, that of continuing in ceaseless vibration, during the whole term of the life of the cells to which they are attached. The length of time during which the ciliary movement continues after the general death of the body, is much less in the warm-blooded than in the cold-blooded animals; and in this respect it corresponds with the degree of persistence of muscular irritability, and of other vital endowments.

236. The Tesselated-Epithelium, as already mentioned, covers the Serous and Synovial membranes, the lining membrane of the blood-vessels and absorbents, and the Mucous membranes with their glandular prolongations, except where the cylinder-epithelium exists. It presents itself, with some modifications presently to be noticed, in the ultimate follicles of all glands, and also in the air-cells of the lungs. In this latter situation it is furnished with cilia; and these are also found on the cells of the tesselated-epithelium, which covers the deli-

cate pia mater lining the cerebral cavities.—The Cylinder-Epithelium commences at the cardiac orifice of the stomach, and lines the whole intestinal tube; and, generally speaking, it lines the larger gland-ducts, giving place to the tesselated form in their smaller ramifications. A similar epithelium, furnished with cilia, is found lining the air-passages and their various offsets,—the nasal cavities, frontal sinuses, maxillary antra, lachrymal ducts and sac, the posterior surface of the pendulous velum of the palate and fauces, the Eustachian tubes, the larynx, trachea, and bronchi,—becoming continuous, however, in the finer divisions of the latter, with the ciliated pavement-epithelium. The upper part of the vagini, the uterus, and the Fallopian tubes, are also furnished with a ciliated Cylinder-epithelium. The function of the cilia in all these cases appears to be the same; that of propelling the viscid secretions, which would otherwise accumulate on these membranes, towards the exterior orifices, whence they may be carried off.

237. The simplest office which the Epithelium-cells of Mucous membranes perform, appears to be that of elaborating a peculiar secretion, termed *Mucus;* which is destined to protect them from the contact of air, or from that of the various irritating substances to which they are exposed, in consequence of their peculiar position and functions. This Mucus is a transparent semi-fluid substance, distinguished by its peculiar tenacity or viscidity. It is quite insoluble in water; but is readily dissolved by dilute alkaline solutions, from which it is precipitated again by the addition of an acid. A substance resembling Mucus may be produced from any fibrinous exudation, or even from pus, by treating it with a small quantity of liquor potassæ. The secretion of Mucus, like the formation of Epidermis, appears to take place with an activity proportioned to the degree of irritation of the subjacent membrane. On many parts of the mucous surface, a sufficient supply is afforded by the epithelium-cells which cover it; but in other situations, especially along the alimentary canal, the demand is much greater, and it is supplied not merely by the cells of the surface, but by those lining the crypts or follicles which are formed by involutions of it. There is reason to believe that the whole epithelial covering of the stomach and intestinal tube (along the upper part of the latter at least) is cast off at every meal (Fig. 27); the cells growing from their germs, elaborating their mucous secretion, and then bursting or liquefying to set this free, in the course of a few hours. The *debris* of these secreting cells may be recognized in the substances voided from the intestine; as well as in the mucus taken from the surface of any mucous membrane.

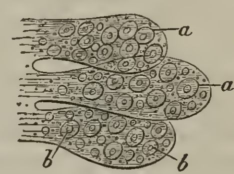
238. The Epithelium-cells, which are thus being continually renewed on the Mucous surfaces, commonly seem to have their origin in the granular germs diffused through the basement-membrane; but it is different in regard to the cells of the follicles, which seem rather to occupy their cavity than merely to line their walls, and which appear to be in course of continual production from a *germinal spot*,

or collection of reproductive granules, at the blind extremity of the follicle. This is the case in the ultimate follicles of the more complex glands; which may be regarded as so many repetitions of the simple crypts or follicles in the substance of the mucous membranes;—the only difference being, that the former pour their secretion into a branch of a duct, which unites with the other ramifications to form a trunk; and this trunk conveys them to their destination in some cavity lined by a mucous membrane;—whilst the simple follicles or crypts at once pour forth their secretions upon the surface of the membrane. The accompanying figure represents two follicles of the

Fig. 23.

Two follicles from the liver of *Carcinus mœnas*, (Common Crab), with their contained secreting cells.

Fig. 24.



Ultimate follicles of Mammary gland, with their secreting cells, *a*, *a*;—*b*, *b*, the nuclei.

liver of the Common Crab, which are seen to be filled with secreting cells; it is evident, from the comparative sizes of these cells in different parts, that they originate at the blind extremity of the follicle, where there is a germinal spot; and that, as they recede from that spot, they gradually increase in size, and become filled with their characteristic secretion, being at the same time pushed onwards towards the outlet by the continual new growth of cells at the germinal spot. In Fig. 24 are shown the corresponding ultimate follicles of the Mammary gland; filled, like the preceding, with secreting cells.

239. The whole of the acts, then, by which the separation of the different Secretions from the Circulating fluid is accomplished, really consist in the growth and nutrition of a certain set of cells, usually covering the free surfaces of the body, both internal and external, or lining cavities which have a ready communication with these by means of ducts or canals.* These cells differ widely from one another, in regard to the kind of matter which they appropriate and assemble in their cavities; although the nature of their walls is probably the same throughout. Thus we find biliary matter and oil, easily recognizable by their colour and refracting power, in the cells of the liver; milk in the cells of the mammary gland; sebaceous or fatty matter in the cells of the sebaceous follicles of the skin; and so on. All these substances are derived from the blood; being either contained in it previously, or being elaborated from its constituents

* The Synovial secretion is, perhaps, the only one which is poured into a closed sac.

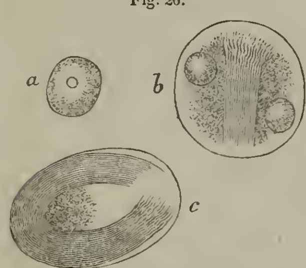
by a simple process of transformation,—as, for example, that which converts the albumen of the blood into the casein of milk. Hence they may be considered as the peculiar aliments of the several groups of cells; whose acts of *nutrition* are the means of drawing them off or *secreting* them, from the general circulating fluid. When they have attained their full growth, and accomplished their term of life, their walls either burst or dissolve away, and thus the contents of the cells are delivered into the cavity, or upon the surface, at which they are required. Now as all the canals of the glands open either directly outwards upon the surface, or into cavities which communicate with the exterior, it is evident that the various products of the action of these epithelial cells must be destined to be cast forth from the body. This we shall find to be the case; some of them, as the bile and urine, being excretions, of which it is necessary to get rid by the most direct channel; whilst others, like the tears, the saliva, the gastric fluid, the milk, &c., are separated from the blood, not so much for *its* purification, but because *they* are required to answer certain purposes in the economy.

Fig. 25.

Secreting cells of Human Liver; *a*, nucleus; *b*, nucleolus; *c*, oil-particles.

240. Now whilst thus actively concerned in the Nutritive functions of the economy, and exercising in the highest degree their powers of selection and transformation, these Secreting cells appear to have nothing to do with the operation of Reproduction. We have seen that they do not even regenerate themselves; all their energies being, as it were, concentrated upon their own growth; and the successive production of new generations being provided for by other means. But special *Reproductive* cells, destined to furnish the germs for the continuance of the race, are not wanting. These are developed within the tubuli of the Testicle; where they appear to hold exactly the same relation to the membranous walls of those tubuli, as do the secreting cells to the tubes and follicles of the proper Glands. The contents of these reproductive cells are peculiarly granular; and the granules are at one time diffused through the entire cell. They are afterwards seen, however, to present a regular linear arrangement; forming a bundle of fibrous bodies, still comprehended, however, within the cell. After a time, however, the containing cells burst, and the fibrous bodies within separate and are set free. From the very peculiar motion which they possess, they were long regarded as distinct Animalcules, and received the designation of Spermatozoa. It is now generally admitted, however, that they have

Fig. 26.



Formation of Spermatozoa within seminal cells; *a*, the original nucleated cell; *b*, the same enlarged, with the formation of the Spermatozoa in progress; *c*, the Spermatozoa nearly complete, but still enclosed within the cell.

no more claim to a distinct animal character, than have the ciliated epithelia of mucous membrane, which will likewise continue in movement when separated from the body. The so-called Spermatozoa appear to be nothing else than cell-germs, furnished with a peculiar power of movement, by means of which they are enabled to make their way into the situation where they may be received, cherished, and developed,—as will be shown hereafter. (Chap. XI.) It is a curious fact that the seminal cells, in which the Spermatozoa are formed, are sometimes ejected from the gland, not only before they have burst and set free the Spermatozoa, but even long before the development of the Spermatozoa in their interior is completed;—thus affording a complete demonstration of their independent vitality.

241. We now proceed to a class of cells, which are equally independent of each other, which begin and end their lives as cells, without undergoing any transformation, but which form part of the substance of the fabric, instead of lying upon its free surfaces and being continually cast off from them. Still their individual history is much the same as that of the cells already noticed; and they differ chiefly in regard to the destination of their products.—The first group of this class deserving a separate notice, is that which effects the introduction of aliment into the body;—of those kinds of aliment, at least, which are not received in solution by any more direct means. Along the greater part of the intestinal tube, from the point at which the hepatic and pancreatic ducts enter it, to the rectum, we find the mucous membrane furnished with a vast number of minute tufts or folds, by which its free surface is vastly extended; these are termed *villi*. They may be compared to the ultimate root-fibres of trees, both in structure and function; for each of them gives origin to a minute lacteal or chyle-absorbing vessel, which occupies its centre; whilst it also contains a copious network of blood-vessels, (Fig. 8, p. 118,) which appears likewise to participate in the act of absorption, by taking up substances that are in complete solution. Now at the end of every villus, there may be seen, whilst the process of digestion and absorption is going on, a cluster of minute cells, in the midst of which the origin of the lacteal is lost. These cells, whose size varies from 1-1000th to 1-2000th of an inch, are turgid with a milky fluid, which is evidently the same with that which is found in the lacteals; and there is good reason to believe, that it is by the growth and nutrition of these cells, that this milky fluid, the chyle, is selected from the contents of the digestive cavity. Their function, therefore, is precisely the converse of that of the secreting cells already described; whilst the history of their individual lives is the same. These absorbent cells draw their materials from the fluid in the digestive cavity, instead of from the blood; and when they burst or liquefy, they set free their contents where they may be taken up by a lacteal and conveyed into the circulating current, instead of pouring them into a cavity through which they will be shortly expelled.

242. In the intervals of the digestive process, the extremities of the

villi are comparatively flaccid; and instead of cells, they show merely a collection of granular germs. These begin to develop themselves, as soon as the food has been dissolved in the stomach and transmitted to the intestine; and their development goes on, as long as the villi are surrounded with nutrient matter. The cells rapidly grow, select, absorb, and prepare the nutritious matter, by making it a part of themselves; and, when their work is accomplished, they deliver it to the lacteals by their own rupture or deliquescence. The accompanying diagrams represent the comparative condition of the Mucous

Fig. 27.

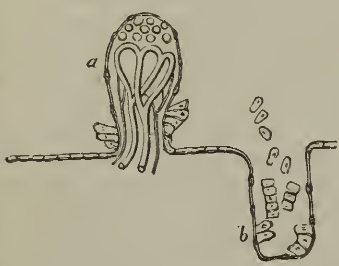


Diagram of mucous membrane during digestion and absorption of chyle; *a*, a villus, turgid and erect; its protective epithelium cast off from its free extremity; its absorbent vesicles, its lacteals, and its blood-vessels turgid; *b*, a follicle discharging its secreting epithelial cells.

Fig. 28.

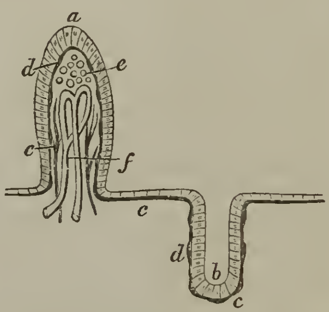


Diagram of mucous membrane of jejunum, when Absorption is not going on; *a*, protective epithelium of a villus; *b*, secreting epithelium of a follicle; *c*, *c*, *c*, primary membrane, with its germinal spots or nuclei, *d*, *d*; *e*, germs of absorbent vesicles; *f*, vessels and lacteals of villus.

membrane, its villi, and its secreting follicles, during the time when absorption is going on, and in the intervals of the process. It will be seen that, in the former state, the epithelium-cells are not only being cast off from the free surface of the membrane, and from the interior of the follicles; but they are also detached from the surface of the villus, that they may offer no impediment to the process of absorption. During the intervals of digestion, the secreting epithelium of the follicles, and the protective epithelium of the villi, are alike renewed, from the germs supplied by the basement-membrane.

243. Although the mucous membrane of the intestinal tube is the only channel through which insoluble nutriment can be absorbed in the completely-formed Mammal, and the only situation, therefore, in which we meet with these absorbent cells, there are other situations in which similar cells perform analogous duties in the embryo. Thus the Chick derives its nutriment, whilst in the egg, from the substance of the yelk, by absorption through the blood-vessels spread out in the vascular layer of the germinal membrane surrounding the yelk; which vessels answer to the blood-vessels and lacteals of the permanent digestive cavity, and are raised into folds or villi as the contents of the yelk-bag are diminished. Now the ends of the vessels are separated from the fluid contents of the yelk-bag, by a layer of cells;

which seems to have for its object to select and prepare the materials supplied by the yelk, for being received into the absorbent vessels.

244. In like manner, the embryo of the Mammal is nourished, up to the time of its birth, through the medium of its umbilical vessels; the ramifications of which form tufts, that dip down, as it were, into the maternal blood, and receive from it the materials destined to the nutrition of the fœtus; besides effecting the aëration of the blood of the latter, by exposing it to the more oxygenated blood of the mother. Now around the capillary loop of the fœtal tuft, there is a layer of cells, closely resembling the absorbent cells of the villi; and these are enclosed in a cap of basement-membrane, which completes the fœtal portion of the tuft, and renders it comparable in all essential respects to the intestinal villus. It is again surrounded, however, by another layer of membrane and of cells, belonging to the maternal system;—the derivation and arrangement of which will be explained hereafter. The maternal cells (*b*, Fig. 29) may be regarded as the

Fig. 29.

Extremity of a placental villus:—*a*, external membrane of the villus, continuous with the lining membrane of the vascular system of the mother; *b*, external cells of the villus, belonging to the placental decidua; *c*, *c*, germinal centres of the external cells; *d*, the space between the maternal and fœtal portions of the villus; *e*, the internal membrane of the villus, continuous with the external membrane of the chorion; *f*, the internal cells of the villus, belonging to the chorion; *g*, the loop of umbilical vessels.

first selectors of nutriment from the circulating fluid of the parent: the materials, partially prepared by them, are poured into the cavity (*d*) surrounding the extremity of the tuft; and from this they are taken up by the fœtal cells (*f*), which further elaborate them, and impart them to the capillary loop (*g*) of the umbilical vessels.

245. Thus we see that the several functions of Selection, Absorption, Assimilation, Respiration, Secretion, and Reproduction, are performed by the agency of cells in the Animal as in the Vegetable kingdom,—in the complex Human organism, as in the humblest Cryptogamic Plant; the only difference being, that in the latter there is a greater division of labour, different groups of cells being appropriated to different functions, in the general economy, whilst the history of their own processes of nutrition and decay is everywhere essentially the same. Thus we have seen that the *Absorbent* cells, at the extremities of the intestinal or placental villi, select and draw into themselves, as the materials of their own growth, certain substances in their neighbourhood; which are still as much external to the tissues of the body, as are the fluids surrounding the roots of plants. Having come to their full term of life, they burst or dissolve away, and give up their contents to the absorbent vessels, which carry them into the general current of the circulation, where they are mingled with the fluid previously assimilated,—the blood. Whilst passing through the vessels, they are subjected to the action of another set of cells, (the

lymph and chyle-corpuscles, and the colourless corpuscles of the blood,) by which they are gradually assimilated, or converted into a substance of a more directly organizable character; these *assimilating* cells being developed from germs that float in the fluid, drawing into themselves the albuminous matter, converting it into fibrin, and then setting it free by their own dissolution. In the same fluid another set of cells, the red corpuscles of the blood, are observed to float, in the higher classes of animals; whose special function appears to be the conveyance of oxygen from the lungs to the tissues, and of carbonic acid from the tissues to the lungs; in other words, that of *Respiration:* these cells do not appear to pass through their course of existence as rapidly as the preceding. Next we have various groups of cells, external to the vessels, on the free surfaces of the body; whose office it is to draw from the blood certain materials, which are destined for *Secretion* or separation from it; either for the sake of preserving that fluid in its requisite purity, or for answering some other purpose in the system. These cells grow at the expense of the substances, which they draw into themselves from the blood; and on their dissolution, they cast forth their contents on the free surfaces communicating with the exterior of the body, to which they are in time conveyed. And, lastly, we have a special set of cells, destined to prepare the germs of new beings; which are, in like manner, set free by the rupture of the parent-cell, in a condition that enables them to be conveyed to a place appropriated for their further development, and thus to perform the essential part of the process of *Reproduction.*

246. The cells which are thus the active instruments of the Organic functions, are produced and succeed one another with a rapidity proportional to the energy of those functions. The causes which influence their growth and decay are not always evident; thus we occasionally find an extraordinary tendency to the elaboration of Fibrin, as manifested in the increase in the proportion of that ingredient of the blood, and in the number of the Assimilating cells or white corpuscles that float in that fluid; and as to the causes of this condition, which is one important part of the disordered state termed Inflammation, we are almost entirely in the dark. The development of the Absorbent cells appears to depend upon the supply of alimentary materials afforded by the contents of the digestive cavity; and also upon the supply of blood furnished by the capillaries of the villi, from which last the materials of the cell-walls are probably derived. The conditions of the development of the Secreting cells are not sufficiently understood; it does not appear to depend solely upon the supply of their materials; for, as we shall see hereafter, these materials may accumulate unduly in the blood, through the insufficient production of the cells which are destined to separate them; whilst, on the other hand, the presence of certain substances in the blood appears to accelerate their development. Of these stimuli, Mercury is one of the most powerful; and we have continual opportunities of witnessing its effects, in giving an

increased activity to the secreting actions. There is probably not a gland in the body, which is not in some degree influenced by its presence in the blood; but the liver, the kidneys, the salivary glands, and the glandulæ of the intestinal canal, appear to be those most affected by its stimulating powers. The action of the glands, in other words the development of the secreting cells, appears to be influenced by mental emotions; being sometimes accelerated, and sometimes retarded, through their agency. This is especially the case in regard to the secretion of Milk, Tears, Saliva, and Gastric juice. But we shall hereafter see that the influence thus manifested is probably exerted through the capillary circulation, which is known to be powerfully affected by mental emotions, as in the acts of blushing and erection; and that the increased production of the secretion is immediately due to the increased flow of blood to the gland. We have an example of this, in the "draught" (as it is termed) experienced by Nurses, when the child is applied to the breast; which is a perceptible rush of blood into the organ.

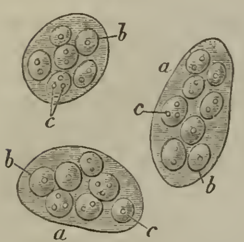
5. *Of Cells connected together as permanent constituents of the Tissues.*

247. We now pass on to consider those Cells which enter as component elements into the solid and permanent fabric of the body, and which do not take so active a part in its vital operations. These we shall find to be usually more or less closely connected together, either by a general enveloping membrane, or by an *intercellular substance*, which is interposed between their walls, and holds them together by its adhesive properties. Before entering upon the description of the tissues thus formed, it will be desirable to consider a little more fully the mode in which the component cells are developed, and the character of the transformations they may undergo.

248. We have seen that a minute isolated molecule, prepared by a parent-cell, and set free by its dissolution, may become the germ of a new cell; and that the assimilating cells which float in the animal fluids seem to have their origin, like the equally-simple cells of the Yeast-fungus, in such floating germs; whilst the epithelial and epidermic tissues arise from similar granules diffused through the substance of the basement-membrane, or aggregated in its germinal spots. But the usual mode of development of the cells of a higher and more permanent character, is somewhat different; for these are developed *within* the parent-cell, which, instead of dissolving away, may remain as a thin membrane around them;—all traces of it, however, at last disappearing, in consequence of the distension which it undergoes. Even whilst still evidently contained within the parent-cell, the secondary cells may themselves be developing a third generation within them. The rapidity of the process, and the number of cells thus developed, appear to bear a close relation with the transitory or permanent character of the structure. It is in Cancerous growths, that we meet with the most remarkable examples of rapid production;

a large number of secondary cells being developed within each primary; these secondary cells again becoming the parents, each one of an equally large generation; and so on. Here the whole energy seems concentrated upon the reproductive process; and we find that growths composed of such cells have a very rapid increase, but very little solidity or permanence.—On the other hand we find that, in structures which are destined to undergo a higher development, and to possess a more permanent character, the number of cells developed within each parent is more limited; thus in the early development of the embryo of Mammalia it is limited to *two;* and the first pair of cells is thus progressively developed into four, eight, sixteen, and so on. The same tendency to a *binary* multiplication is apparent also in the cells of Cartilage (§ 267); and it probably exists also in other cellular structures of a permanent character.

Fig. 30.



Parent-cells, *a, a,* of cancerous structure, containing secondary cells, *b, b,* each having one, two, or three nuclei, *c, c.*

249. It is most commonly to be observed in these cells, that the reproductive granules, instead of being diffused throughout the cavity of the cell,—as they are in the cells of the Cryptogamic Plants, the White Corpuscles of the blood of Animals, &c. &c.,—are concentrated in one spot, forming a *nucleus* (Figs. 20, 21); and it is from this nucleus that the new cells originate. The granules appear to undergo the same changes, when developed in this situation, as they do when isolated within the cell, or altogether set free; at first they show a simple enlargement, looking like little warts projecting into the cell; this enlargement continues, until the difference between the cell-wall and the cavity, the containing and the contained parts, becomes perceptible; and the character of the young cell is then obvious.

250. According to Dr. Barry's observations on the processes of cell-growth in the germinal vesicle and early embryo of the Rabbit, it is the outer circle of granules forming the nucleus, which is first developed into young cells; the next then commences, and pushes outwards the ring of cells previously formed; and by the continuance of the same process, the parent-cell may be completely filled with a new generation. Of these, however, the greater part may be destined to liquefy or dissolve away; their office having apparently been, to assimilate or prepare the materials that are destined for the nutrition of the permanent offspring, which are the cells latest formed in the centre of the nucleus. A pellucid spot, which is frequently seen in the centre of the nucleus, has received the name of *nucleolus* (Fig. 20, *c*); sometimes two or even three nucleoli may be seen in a single nucleus (Fig. 21, *a*). The cause of this appearance is not precisely understood; but it seems to be of a transitory character, indicating a certain stage in the conversion of the nucleus into new cells.

251. The function of the nucleus in the development of new cells, is thus evidently identical with that of the "germinal spots" already described as existing at the extremity of the secreting follicles (§ 238), or in the substance of the basement-membrane. In fact we are probably to regard each secreting follicle as a large parent-cell; of which the functions are permanent, instead of transitory; and which, having opened into a neighbouring duct, instead of remaining closed, continues to develop new secondary or secreting cells, from the nucleus or germinal spot at its opposite extremity, to an unlimited extent. And it is probable, also, that the "germinal spots" in the substance of the basement-membrane are really the nuclei of cells, by the coalescence of which it is formed, in the manner to be presently noticed.

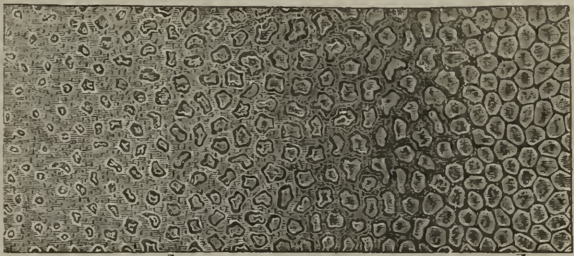
252. Now if the walls of the parent-cells, instead of liquefying or thinning away, are thickened or strengthened by additional nutrition, they may remain as permanent vesicles, enclosing and holding together numerous secondary cells; and this appears to be the case in Adipose tissue, and also in tumours of various kinds.

253. Where such enveloping membranes are wanting, we frequently find the component cells of the permanent tissues of Animals (like those of the higher plants) held together by an *intercellular* substance; which generally presents no distinct traces of organization; and which usually consists of Gelatin, or of a substance allied to it in composition. The proportion of this substance to the cells may vary in different cases; and very different characters may thus be presented by a tissue made up of the same elements. Thus the subjoined figure represents a portion of one of the animal layers included between the calcareous laminæ of a bivalve shell; in which we see on the one side a number of nuclei or incipient cells, scattered through a bed of homogeneous intercellular substance, and bearing but a very small proportion to it; whilst the opposite end exhibits a set of polygonal cells, in close contact with each other, the intercellular substance being only represented by the thick dark lines, which mark the boundaries of the cells, and which are rather thicker at the angles of the latter. Between these two extremes, we observe every stage of transition.

254. The presence of a very large amount of intercellular substance, through which minute cells are scattered at considerable intervals, (Fig. 31, *a*,) is characteristic of various forms of Cartilage; and more particularly of that soft semi-cartilaginous structure, of which the Jelly-fish are for the most part composed. In other forms of cartilage, we find the cells more developed, and in closer proximity to each other, the proportion of the intercellular substance being at the same time diminished (as seen at *b* and *c*, Fig. 31); but it is not often, save in embryonic structures, that we find the cells in such close proximity, and the intercellular substance so nearly wanting, as at *d*. Such examples do occasionally present themselves, however, even in the soft tissues. Thus the *chorda dorsalis*, which replaces the vertebral column in the lowest Fishes, and of which the analogue is found in the embryos of the higher Vertebrata, is made up of a structure of

this kind. The true Skin, in the Short Sun-fish, is replaced by a similar layer of cellular tissue, which extends over the whole body, varying in thickness from one-fourth of an inch to six inches. And

Fig. 31.

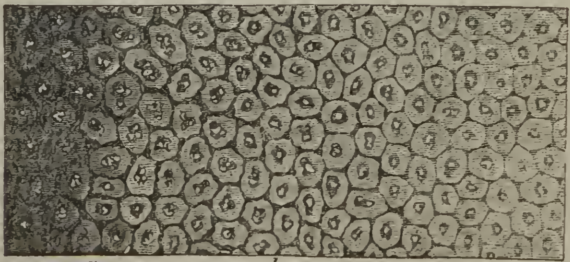


Portion of shell-membrane, showing the origin of cells in the midst of horny intercellular substance; *a*, nuclei; *b*, incipient cells; *c*, the same further advanced, but separated by intercellular substance *d*, the cells become polygonal by mutual pressure.

in the Lancelot (a little fish which is destitute of so many of the characters of a Vertebrated animal, that its right to a place in that division has been doubted), a considerable portion of the fabric is made up of a similar parenchyma.

255. Now we shall find that one method, by which the requisite firmness and solidity are given to the animal fabric, consists in the deposition of earthy substances in the interior of such cells, by a peculiar secreting action of their own. Thus in Shell, we find them completely filled up with carbonate of lime; and in Bones and Teeth with carbonate and phosphate of lime. When this is the case, there is a tendency to an apparent *coalescence* of the cells, by the obliteration of their partitions; or rather, perhaps, by the removal of the whole intercellular substance from between them, the actual cell-walls being so very thin, that they are not distinguishable. The incipient stages of this coalescence, as seen in another portion of the same membrane as that represented in the last figure, are shown in Fig. 32. At *a*,

Fig. 32.



Portion of shell-membrane, showing the gradual coalescence of distinct cells; at *a*, the cells separated by intercellular substance; at *b*, the partitions are thinner; and at *c*, they almost disappear.

the nucleated cells are very distinct; and are separated by a large quantity of intercellular substance. At *b*, they approach each other more closely, the amount of intercellular substance being less; the widest intervals are seen at the angles of the cells. At *c*, the approximation is much closer; and the cell-walls are scarcely distinguishable at the points where they come into immediate contact. Proceeding further, we observe that the partitions are much less complete; so that the originally distinct cellular character of the membrane is chiefly indicated by the bright nuclei, which are regularly dispersed through it, and by the triangular dark spots, which show the remains of the intercellular substance at the angles where three cells join each other. The coalescence may be traced further than it is shown to do in the figure; so that, if it were not for the evidence afforded by the transition-stages here represented, it would be difficult to prove that the membranous layer had its origin in cells.

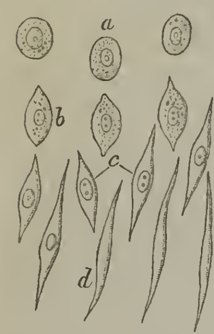
256. These facts, respecting the gradual coalescence of cells, explain not merely the appearances presented in Tooth, Shell, &c. (hereafter to be described); but also those which are exhibited by the Basement-membrane, as already detailed (§ 206.)

257. There is no evidence, in the preceding case, that the *cavities* of the cells coalesce; and there is no reason why they should do so. But we often find such an union, where the production of a continuous tube is required. The long straight open ducts, through which the sap of Plants rises in the stem, are unquestionably formed by a coalescence of the *cavities* of cells of a cylindrical form, placed regularly end to end; and it seems probable that the network of anastomosing vessels, through which the elaborated sap finds its way to the various parts of the vegetable fabric, is formed, in like manner, by the coalescence of cells, arranged obliquely and transversely in regard to one another. In like manner, the capillary Blood-vessels of Animals are usually believed to originate in rows of cells, the cavities of which have run together by the obliteration of the transverse partitions; as the persistent nuclei of such cells may be occasionally brought into view in the walls of the capillaries. And the same appears to be the origin of the tubular fibres of Muscular and Nervous tissue, which contain the elements characteristic of those tissues; these elements,—the fibrillæ of muscle, and the granular pith of the nerve-tube,—being evidently the secondary products of parent-cells, which seem to remain as their investing tubuli, in the walls of which the original nuclei are often to be seen (§§ 338 and 388).

258. Besides these changes, the original cells may often undergo marked alterations of form; and this quite independently of any pressure to which they may be subject. Thus the pigment-cells, as already mentioned (§ 229,) frequently exhibit a curious *stellate* form; arising from the development of radiating prolongations, which are put forth from the original spheroid. A form which is frequently assumed by the cells that are developed in fibrinous or plastic exudations, and which is also met with in the cells of tumours, both

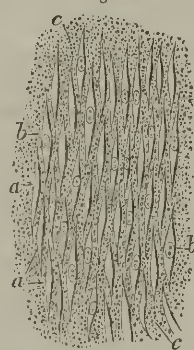
malignant (or Cancerous) and non-malignant, is that which has received the designation of *fusiform* or spindle-like, from its prolonged shape and pointed extremities. The various stages of transition, which may be observed between the simple rounded cell and the fusiform cell, are shown in Fig. 33; and it is there seen that, when the transformation has gone to its utmost extent, the nucleus of the cell is no longer visible, so that it bears a close resemblance to a simple fibre. Such cells are found amongst the simple fibrous tissues; and, in the opinion of many, they give origin to them.—The appearance of tissue, composed of fusiform cells, is shown in Fig. 34; this is seldom met with as a permanent part of the normal fabric; but it is a frequent product of morbid action.

Fig. 33.



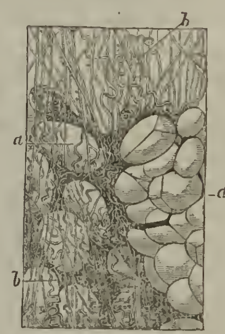
Transition from cellular to fusiform tissue; *a*, circular or oval cells; *b*, the same becoming pointed; *c*, fusiform cells containing nuclei; *d*, fusiform cells more elongated, and destitute of nuclei.

Fig. 34.



Fusiform tissue of plastic exudations; *a*, fusiform bodies without nuclei; *b*, nucleated fusiform cells; *c*, granular intercellular substance.

Fig. 35.



Areolar and Adipose tissue; *a*, *a*, fat-cells; *b*, *b*, fibres of areolar tissue.

259. We now proceed with the description of the various tissues in the Human body, which are composed of cells united or transformed in the foregoing manner; and we shall commence with *Adipose* or *Fatty* tissue, which may be considered as a sort of link, connecting the permanent tissues with those which are more actively concerned in the processes of Nutrition, Secretion, &c. The Adipose tissue is composed of isolated cells, which have the power of appropriating fatty matter from the blood, precisely in the same manner as the secreting cells appropriate the elements of bile, milk, &c. These cells are sometimes dispersed in the interspaces of the Areolar tissue; whilst in other cases they are aggregated in distinct masses,—constituting the proper Adipose tissue. In the former case they are held in their places by fibres, that traverse the areolæ in different directions; whilst in the latter, each small cluster of fat cells is included in a common envelop, on the exterior of which the blood-vessels ramify; and these sacculi are held together by areolar tissue. We are thus probably to regard each fatty mass in the light of a gland, or assem-

blage of secreting cells, penetrated by blood-vessels, and bound together by fibrous tissue; but having its follicles closed instead of open, (which, as just now stated, appears to be the early conditions of the follicles of *all* glands, § 251;) and consequently retaining its secretion within itself, instead of pouring it forth into a channel for excretion.

260. The individual fat-cells always present a nearly spherical or spheroidal form; sometimes, however, when they are closely pressed together, they become somewhat polyhedral, from the flattening of their walls against each other. Their intervals are traversed by a minute network of blood-vessels, from which they derive their secretion; and it is probably by the constant moistening of their walls with a *watery* fluid, that their contents are retained without the least transudation, although they are quite fluid at the temperature of the living body. If the watery fluid of the cell-walls of a mass of Fat be allowed to dry up, and it be kept at a temperature of 100°, the escape of the contained oily matter is soon perceptible.—By this provision, the fatty matter is altogether prevented from escaping from the cells of the living tissues, by gravitation or pressure; and as it is not itself liable to undergo change when secluded from the air, it may remain stored up, apparently unaltered, for an almost unlimited period.

Fig. 36.

Capillary network around Fat-cells.

261. The consistency, as well as the Chemical constitution, of the fatty matter contained in the Adipose cells, varies in different animals, according to the relative proportions of three component substances, which may be distinguished in it,—Stearine, Margarine, and Oleine. The two former are solid when isolated, and the latter is fluid; but at the ordinary temperature of the warm-blooded animal, they are dissolved in it. Of these, *Stearine* is the most solid; and it is most largely present, therefore, in the hardest fatty matter, such as mutton-suet. It is crystaline like spermaceti; it is not at all greasy between the fingers, and it melts at 143°. It is insoluble in water, and in cold alcohol and ether; but it dissolves in boiling alcohol or ether, crystalizing as it cools. The substance termed *Margarine* exists along with stearine in most fats; but it is the principal solid constituent of Human fat, and also of Olive oil. It corresponds with Stearine in many of its properties, and is nearly allied to it in Chemical composition; but it is much more soluble in alcohol and ether, and it melts at 118°. On the other hand, *Oleine*, when pure, remains fluid at the zero of Fahrenheit's thermometer; and it is soluble in cold ether, from which it can only be separated by the evaporation of the latter. It exists in small quantity in the various solid fats; but it constitutes the great mass of the liquid fixed oils. The tendency of these to solidification by cold, depends upon the proportion of

stearine or margarine they may contain. All these substances are neutral compounds, formed by the union of *Stearic*, *Margaric*, and *Oleic* acids, respectively, with a base termed *Glycerine;* this base may be obtained from any fatty matter, by treating it with an alkali, which unites with the acid and forms a soap, setting free the Glycerine. They contain no Nitrogen; and their proportion of Oxygen is extremely small in regard to their amount of the Carbon and Hydrogen: thus Stearine has 142 Carbon and 141 Hydrogen to 17 Oxygen; and in the other substances the proportions are similar. The fatty bodies appear to be mutually convertible; thus margaric acid may be procured from stearic acid, by subjecting it to dry distillation; and there is ample evidence that animals supplied with one of them may produce the others from it.

262. Since these fatty matters are abundantly supplied by the Vegetable kingdom, and are found to exist largely in substances which were not previously supposed to contain them, it is not requisite to suppose, that Animals usually elaborate them by any transforming process from the elements of their ordinary food. The mode in which they are taken into the blood, and the uses to which they are subservient, will be hereafter investigated; but it may be here remarked, that the portion separated from the circulating fluid to form the Adipose tissue, is only that which can be spared from the other purposes, to which the fatty matters have to be applied. Hence the production of this tissue depends in part upon the amount of Fatty matter taken in as food; but this is not entirely the case, as some have maintained; for there is sufficient evidence that animals *may* produce fatty matter by a process of chemical transformation, from the starch or sugar of their food, when there is an unusual deficiency of it in their aliment.

263. The development of Adipose tissue in the body appears to answer several distinct purposes. It fills up interstices, and forms a kind of pad or cushion for the support of movable parts; and so necessary does it seem for this purpose, that, even in cases of great emaciation, some fat is always found to remain, especially at the base of the heart around the origin of the great vessels, and in the orbit of the eye. It also assists in the retention of the animal temperature by its non-conducting power; and we accordingly find a thick layer of it, in those warm-blooded mammals that inhabit the seas,—either immediately beneath their skin, or incorporated with its substance. And it also serves as a reservoir of combustible matter, at the expense of which the respiration may be maintained when other materials are deficient; thus we find that the respiration of hybernating animals is kept up, during the period when they cease taking food (§ 121), by the consumption of the store of fat which was laid up in their bodies, previously to their passing into that state; and it is also to be noticed that herbivorous animals, whose food is scanty during the winter, usually exhibit a strong tendency to such an accumulation, during the latter part of the summer, when their food is most rich and abundant,

in order to supply the increased demand created by the low external temperature of the winter season. Other circumstances being the same, it appears that the length of time during which a warm-blooded animal can live without food, depends upon the quantity of fat in its body; for the rapid lowering of its temperature, which is the immediate cause of its death (§ 117,) takes place as soon as the whole of this store has been exhausted. Of the means by which the fatty secretion is taken back again into the current of the circulation, when it is required for use in the system, we know nothing whatever.

264. In the simpler forms of *Cartilage*, we have an example of a tissue of remarkable permanence, composed entirely of cells scattered through an intercellular substance. This substance has a close resemblance to Gelatin, in composition and properties; but is not identical with it; and has received the distinguishing appellation of *Chondrine*, which marks it as the solidifying ingredient of Cartilage. It requires longer boiling than Gelatin for its solution in water; but the solution fixes into a jelly in cooling, and dries by evaporation into a glue that cannot be distinguished from that of gelatin. Chondrine is not precipitated, however, by tannic acid, but, on the other hand, it gives precipitates with acetic acid, alum, acetate of lead, and protosulphate of iron, which do not disturb a solution of gelatin. That the Chondrine obtained by boiling cartilage is an actual component of that tissue, and is not a product of the operation, appears from the fact that its elementary composition agrees with that of pure cartilage, when analyzed by combustion. According to Mulder, the proportions of the elements are as follows: 32 Carbon, 26 Hydrogen, 4 Nitrogen, 14 Oxygen; with which one-tenth of an equivalent of sulphur is combined. This formula is deduced from the definite compound which Chondrine forms with Chlorine.

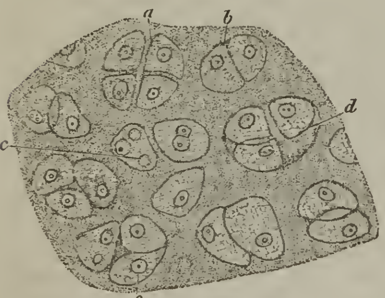
265. Now it is a very curious fact, that all the Cartilages of the fœtus,—those which are to be converted into bone, as well as those which are to remain unossified,—are composed of Chondrine; and yet, as soon as the process of ossification commences, the chondrine is replaced by gelatin, which is the sole organic constituent of the intercellular substance of bones. The permanent cartilages, however, still contain only Chondrine; but if accidental bony deposits should take place in them, (as frequently happens in old persons, especially in the cartilages of the ribs,) the Chondrine gives place to Gelatin. There can be little doubt that, in these cases, there is an actual conversion of the Chondrine into Gelatin; but the mode in which this is effected, is not in the least understood. As Chondrine agrees more nearly with Proteine, in its elementary composition, than Gelatin does, it may be surmised that it is a sort of intermediate stage in the conversion of Proteine into Gelatin; but it must be kept in mind, that no such substance is met with in any other of the gelatinous tissues,—Chondrine being restricted to pure cellular cartilage. Those in which the intercellular substance has the characters of the white fibrous tissue (§ 189), yield gelatin on boiling, in the manner of the

ligaments and tendons; whilst those which contain much of the yellow or elastic tissue, undergo very little change by boiling, and only yield, after several days, a small quantity of an extract which does not form a jelly, but which has the other chemical properties of Chondrine.

266. Besides the organic compounds already described, most Cartilages contain a certain amount of mineral matter, which forms an ash when they are calcined. This ash contains a large proportion of carbonate and sulphate of soda, together with carbonate of lime, and a small quantity of phosphate of lime; as age advances, the proportion of the soluble compounds diminishes, and the phosphate of lime predominates. This is especially the case in the costal cartilages, which almost invariably become converted into a semi-ossified substance, in old persons; and it is remarkable that, even before they have themselves become thus condensed, they are united by ossific matter, when they have undergone fracture.

267. When a pure Cellular Cartilage is examined microscopically, its cells are seen to lie, sometimes singly, and sometimes in clusters of two, three, or four, in cavities excavated in the intercellular substance; and these occur at very variable distances. From the various appearances which may be observed in the same cartilage, at different stages of its growth, it would appear that the component cells multiply by the *doubling* process already described (§ 248); that they then separate from one another, each of them drawing towards itself (as it were) an envelop of intercellular substance; and that, by the repetition of the same process, the number of cells in the cartilage may be indefinitely multiplied. Various stages of this history are shown in the accompanying figure, which is taken from a section of the cartilaginous branchial ray of the larva or tadpole of the Rana esculenta, or Edible Frog. In the centre of the figure are shown three separate cells, which have evidently been at one time in closer proximity with each other. In one of these cells, the nucleus is seen to be developing two new cells in its interior; and a continuation of this process would give rise to the appearance shown at *b*, where two cells are shown in close contact, being evidently the offspring of the same parent. Now if each of these cells in like manner develops two others within itself, a cluster of four will be developed, as shown at *a*; and after a time, intercellular substance being accumulated around

Fig. 37.



Section of the Branchial cartilage of Tadpole; *a*, group of four cells, separating from each other; *b*, pair of cells in apposition; *c*, *c*, nuclei of cartilage-cells; *d*, cavity containing three cells.

each, their walls will separate, and they will acquire the character of distinct cells. It would seem as if, in other cases, one of the first pair of cells develops another pair in its interior, whilst the other (from some unknown cause) does not at once proceed to do so; and thus only three cartilage-cells instead of four are clustered together in the cavity, as seen at *d*.

268. The primitive *cellular* organization now described is retained in some Cartilages through the whole duration of their existence. This is the case, for example, in most of the articular cartilages of joints; in the cartilaginous portion of the septum narium, in the cartilages of the alæ and point of the nose, in the semilunar cartilages of the eyelids; in the cartilages of the larynx, (with the exception of the epiglottis,) the cartilages of the trachea and bronchial tubes, the cartilages of the ribs, and the ensiform cartilage of the sternum. When partial ossific deposits take place, it is usually in the substance of *cellular*, rather than in that of *fibrous* cartilage.

269. When the intercellular substance, instead of being homogeneous, has a fibrous character, the tissue called *Fibro-Cartilage* is produced; and this may be either elastic or non-elastic, according as the yellow or the white form of fibrous structure prevails. In some instances, the fibrous structure is so predominant over the cellular, that the tissue has rather the character of a ligament than of a cartilage. The white fibrous structure is seen in all those cartilages, which unite the bones by synchondrosis, and which are destined not merely to sustain pressure, but also to resist tension. This is the case especially in the substances, which intervene between the vertebræ, and which connect the bones of the pelvis; these in adult Man are destitute of cartilage-corpuscles, except in and near their centres; but in the lower Vertebrata, and in the early condition of the higher, the fibrous structure is confined to the exterior, and the whole interior is occupied by the ordinary cartilage-corpuscles. The yellow-fibrous or reticulated structure is best seen in the epiglottis, and in the concha of the ear; in the former of these, scarcely any trace of cartilage-corpuscles remains; and in the latter, the cellular structure is only to be met with towards the tip.

270. We have seen that the elements of the cellular tissues hitherto described, do not come into direct contact with the blood-vessels. The Epidermic and Epithelial cells are separated from them, by the continuous layer of basement-membrane, which forms the surface of the true skin, the mucous membranes, the glandular follicles produced from them, &c. &c. In like manner, the cells of Adipose tissue are formed within membranous bags; on the outside of which the blood-vessels form a minute network. The cells of Cartilage are not nourished in any more direct manner; and are sometimes at a considerable distance from the nearest vessels. It is certain that the substance of the permanent cellular Cartilages is *not* permeated, in a state of health, even by the minutest nutrient vessels; none such being brought into view under the highest magnifying power. They

are, however, surrounded by vessels, which form large *ampullæ* or varicose dilatations at their edges, or spread over their surfaces; and it is by the fluid which is drawn from them by the Cartilage-cells, that the latter are nourished. The nutrition of a mass of Cartilage thus seems to bear a strong resemblance to that of the thick fleshy Sea-weeds, which are in like manner composed entirely of cells, with

Fig. 38.

Vessels situated between the attached synovial membrane, and the articular cartilage, at the point where the ligamemtum teres is inserted in the head of the os femoris of the human subject, between the third and fourth months of fœtal life;—*a*, the surface of the articular cartilage; *b*, the vessels between the articular cartilage and the synovial membrane; *c*, the surface to which the ligamentum teres was attached; *d*, the vein; *e*, the artery.

intercellular substance disposed between them in greater or smaller amount. The cells in nearest proximity to the nutrient fluid, draw from it the requisite materials, and transmit these to the cells in the interior of the mass, receiving a fresh supply in their turn from the source in their own neighbourhood. When the Articular or other cellular Cartilages are inflamed, however, we find vessels passing into their substance; but these vessels are formed in an entirely new tissue, which is the product of the inflammatory process, and cannot be said to belong to the Cartilage itself.

271. The temporary Cartilages, which have a like cellular structure, but which are destined to undergo metamorphosis into Bone, are equally destitute of vessels when their mass is small; but if their thickness exceed an eighth of an inch, they are permeated by canals for the transmission of vessels. Still these vessels do not ramify with any minuteness in the tissue; and they leave large *islets*, in which the nutritive process must take place on the plan just described.

272. The Fibro-Cartilages, formed as it were by the intermingling of two distinct elementary structures, have a degree of vascularity proportioned to the amount of the fibrous tissue which they contain; but these vessels do not penetrate the cellular portions, where such are distinct from the mixed structure.

273. The Cartilaginous tissue appears to be more removed than almost any other in the body, from the general tide of nutritive action. Its properties are simply of a physical character; and they are not impaired for a long time after the death of the tissue, its tendency to

decomposition being very slight, so long as it is exposed to ordinary temperatures. It is protected by its toughness and elasticity from those mechanical injuries, to which softer or more brittle tissues are liable; and consequently it has little need of any active power of reparation. It seems doubtful whether, when loss of substance occurs as a result of disease or accident, this is repaired by real cartilaginous tissue. In the process of ulceration, as observed by Mr. J. Goodsir, it appears that the formation of depressions in the surface is due, not so much to any change originating in the substance of the Cartilage, as to the eroding action of the cells of the false membrane, which is the product of inflammatory action upon its surface; and it is in this false membrane, that the new vessels are formed, which dip down into nipple-like prolongations of the membrane, that enter corresponding hollows excavated in the cartilage.

274. The *Cornea* of the Eye bears a close resemblance to Cartilage, both in structure and composition; and it corresponds rather with the cellular than with the fibrous form of that tissue. The cells are not so numerous as those of the articular cartilages; and they are surrounded by a plexus of bright fibres, loosely connected together, so as to resemble areolar tissue. Two sets of vessels, a superficial and a deep-seated, surround the margin of the cornea. The former (Fig. 39, A.) belong rather to the Conjunctival membrane, which forms the outer layer of the cornea; and they are prolonged to the distance of one-eighth or half a line from its margin, then returning as veins. The latter (B) do not pass into the true Cornea, but terminate in dilatations from which veins arise, just where it becomes continuous with the sclerotic. In diseased conditions of the Cornea, however, both sets of vessels extend themselves through it. Notwithstanding the absence of vessels in the healthy condition of the corneal tissue, incised wounds of its substance commonly heal very readily, as is well seen after the operation for Cataract; but there is a danger in carrying the incision around a large proportion of its margin, lest the tissue should be too much cut off from the supply of nutriment afforded by the ampullæ of the vessels that surround it.

Fig. 39.

Nutrient Vessels of the Cornea. A. Superficial vessels belonging to the Conjunctival membrane, and continued over the margin of the Cornea; B. vessels of the Sclerotic, returning at the margin of the Cornea.

275. The *Crystaline Lens* of the Eye approaches Cartilage, in its structure and mode of nutrition, more nearly than any other tissue. It may be separated into numerous laminæ; which are composed of fibres that lock into one another, by their delicately-toothed margins. Each of these fibres appears to be made up of a series of cells, linearly

arranged, which coalesce at an early period. The lens is not permeated by blood-vessels; at least after it has been completely formed; these being confined to the capsule. During the early part of fœtal life, and in inflammatory conditions of the Capsular membrane, both its anterior and its posterior portions are distinctly vascular; but at a later period, only the posterior half of the Capsule has vessels distributed upon its surface. It has been shown by optical experiments devised for the purpose, that a moderate vascularity of the posterior capsule does not interfere with distinct vision; whilst if the anterior capsule were traversed by vessels, the picture on the retina would be no longer clear. The substance of which the lens is composed appears to be soluble Albumen, or perhaps more closely resembles the Globulin of the blood.

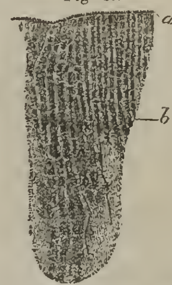
276. The *Vitreous* body, which fills the greater part of the globe of the eye, also seems to possess a cellular structure; the cells containing a fluid, which is little else than water holding in solution a small quantity of albumen and saline matter; and the membrane which forms their walls being so pellucid as to be scarcely distinguishable. Indeed, the cellular character of this substance is chiefly inferred from the fact, that when its capsule or enveloping membrane is punctured, even in several places, the contained fluid does not speedily drain away,—as it would do if it were merely contained in the interstices of an areolar tissue. The blood-vessels which traverse the Vitreous body do not send branches into its substance; and it must derive its nutriment from those which are distributed minutely upon its general envelop, and probably also from the large plexiform vessels of the ciliary processes of the Choroid coat.

277. We next proceed to examine the nature of the tissues, which have a cellular structure at their original basis; but which have undergone a metamorphosis in regard to the arrangement of their elementary parts; and which have received an additional consolidation, by the deposition of earthy matter in their substance. These tissues are the Osseous and the Dental,—Bones and Teeth. The structure of both of them is well adapted to demonstrate the distinction between the tissues themselves, and those subsidiary parts, by which they are connected with the rest of the structure. We have seen that Cartilage is essentially *non-vascular;* that is, even when it exists in a considerable mass, it is not traversed by vessels, but is nourished by absorption from the fluids contained in the vessels distributed on its exterior. Now every mass of Bone *is* penetrated by vessels; nevertheless these do not penetrate its ultimate substance, and may be easily separated from it, leaving the bone itself as it was. In fact, as Mr. J. Goodsir observes, "a well macerated bone is one of the most easily made, and, at the same time one of the most curious anatomical preparations. It is a perfect example of a texture completely isolated; the vessels, nerves, membranes, and fat, are all separated, and nothing is left but the non-vascular osseous substance." Precisely the same may be said of the substance of a Tooth, from which the vascular

lining of the pulp-cavity has been removed; for it then possesses neither vessels, nerves, nor lymphatics; and yet, as we shall presently see, it has a highly-organized structure, peculiar to itself.

278. The general characters of Osseous texture vary according to the shape of the Bone, and the part of it examined. Thus in the *long* bones, we find the shaft pierced by a central canal, which runs continuously from one extremity to the other; and the hollow cylinder which surrounds this is very compact in its structure. On the other hand, the dilated ends of the bone are not penetrated by the large central canal; nor are they composed of solid osseous substance. They are made up of *cancellated* structure, as it is termed; that is, of osseous lamellæ and fibres interwoven together (like those of areolar tissue, on a larger scale) so as to form a multitude of minute chambers or *cancelli*, freely communicating with each other, and with the cavity of the shaft; whilst the whole is capped with a thin layer of solid bone. Again, in the thin flat bones, as the scapula, we find the two surfaces composed of solid osseous texture, with more or less of cancellated structure interposed between the layers. And in the thicker flat bones, as the parietal, frontal, &c., this cancellated structure becomes very distinct, and forms the diploe; this, however, is sometimes deficient, leaving a cavity analogous to the canal of the long bones; whilst the plates which form the surfaces of the bone (the external and internal tables of the skull), resemble in their thickness and solidity, as well as in the intimate structure presently to be described, the shaft or hollow cylinder of those bones. Finally, we frequently meet (especially in the Ethmoid and Sphenoid bones), with thin lamellæ of osseous substance, resembling those which elsewhere form the boundaries of the cancelli; these consist of but one layer of bony matter, and show none of the varieties previously adverted to; they are not penetrated by vessels, but are nourished only by their surfaces; and they consequently exhibit to us the elements of the osseous structure in their simplest form. It will be desirable, therefore, to commence with the description of these.

Fig 40.



Extremity of Os femoris, showing cancellated structure;—*a*, thin layer of bone, in contact with the articular cartilage; *b*, cancelli.

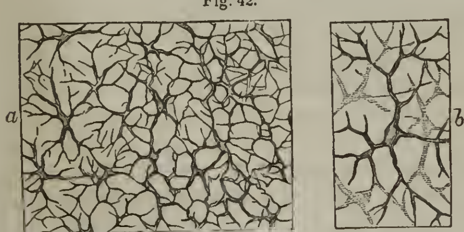
279. When a thin natural lamella of this kind is examined, it is found to be chiefly made up of a substance which is apparently homogeneous, but which may be seen (especially after prolonged boiling) to consist of minute granules, varying in size from 1-6000th to 1-14000th of an inch; these are more or less angular in shape, and seem to cohere by the medium of some second substance, which is dissolved by the boiling. They are composed of Calcareous salts, apparently in chemical union with the Gelatin that forms the basis of the osseous substance. In the midst of this granular substance a number of dark spots are to be observed, the form of which is very

peculiar. In their general outline they are usually somewhat oval; but they send forth numerous radiating prolongations of extreme minuteness, which may be frequently traced to a considerable distance. These spots, known as the *osseous corpuscles*, (sometimes termed the *Purkinjean corpuscles*, after the name of their discoverer,) are highly characteristic of the true bony structure, being never deficient in the minutest parts of the bones of the higher animals, although those of Fishes are frequently destitute of them. These corpuscles were formerly supposed, from their dark appearance, to be opaque, and to consist of aggregations of calcareous matter which would not transmit the light: but it is now quite certain, that they are *lacunæ* or open spaces; and that the radiating prolongations from them, which are far smaller than the minutest capillary vessel, are *canaliculi* or delicate tubes. Of these canaliculi, some may be seen to interlace freely with each other, whilst others proceed towards the surface of the bony lamella; and thus a system of passages, not by any means wide enough to admit the blood-corpuscles, but capable of transmitting the fluid elements of the blood, or matters selected from them, is established through the whole substance of the lamella. The lacunæ have an average length of 1-1800th of an inch; and they are usually about half as wide, and one-third as thick. The diameter of the canaliculi is from 1-12000th to 1-20000th of an inch. The succeeding figure represents the arrangement of these lacunæ and canaliculi in the bony scale of a Fish (the Lepidosteus); which is almost the only existing representative of a large class of bony-scaled Fishes, that formerly tenanted the seas. This subject is selected on account of the peculiar distinctness with which these elementary parts are shown; and the entire absence of any of that more complex arrangement, caused by the penetration of blood-vessels, which we shall presently have to describe.

Fig. 41.

Lacunæ of Osseous substance, magnified 500 diameters;—*a*, central cavity; *b*, its ramifications.

Fig. 42.



Section of the bony scale of Lepidosteus;—*a*, showing the regular distribution of the lacunæ and of the connecting canaliculi; *b*, small portion more highly magnified.

280. The lacunæ of the solid osseous texture are not unoccupied, however, in the living Bone. They are filled with a minute granular substance; which is probably to be regarded (as first pointed out by Mr. J. Goodsir) in the light of a germinal spot or nutritive centre,

that has the power of drawing to itself, through its own system of canaliculi, the nutritive materials supplied by the blood-vessels on the nearest surface, and of diffusing these through the surrounding substance. Between the blood-vessels and the surface of the bony lamella, however, there is a layer of cells; which are probably the immediate agents in the selection and elaboration of the nutritive matter, and which then deliver it to be taken up by the canaliculi.—Thus the nutrition of the ultimate osseous texture is carried on upon the same plan with that of Cartilage; being effected by the imbibition of nutrient matter from the surface, through the agency of cells. But it differs in this;—that there is a provision in Bone for the ready transmission of nutrient matter through its texture, by means of minute channels, which does not exist in Cartilage;—a difference obviously required by the greater solidity of the substance of the former, which does not allow of the diffused imbibition, that is permitted by the softer and moister nature of the latter. We shall presently find that they are only formed at a late stage of the development of bone, when the remaining tissue has acquired its completest consolidation.

281. Now, as already remarked, the simple structure just described is found, not merely in the delicate plates which form the thinnest part of certain bones in Man; but also in those lamellæ, which form the walls of the *cancelli* of the larger and thicker bones. Every one of these lamellæ repeats, in fact, the same history. The cancelli are lined by a membrane derived from that of the cavity of the shaft, over which blood-vessels are minutely distributed; between these blood-vessels and the osseous texture, is a layer of cells; and from the materials selected and communicated by these, each lamella is nourished, through its system of radiating canaliculi and nutritive centres. The cancelli, at the time of their formation in the fœtal bone, are entirely filled with such cells; which appear (as will be presently explained) to be the descendants of the cells of the original cartilage; but in the adult bone, a large proportion of them is filled with fatty matter, which they secrete into their cavities.—The vessels of the cancellated structure at the extremities of the long bones, are derived from those of the medullary cavity, which is penetrated by large trunks from the exterior; and in the flat bones, they form a system of their own, connected with the vessels of the exterior by several smaller trunks.

282. The solid osseous texture, which forms the cylindrical shafts of the long bones, and the thick external plates of the denser flat bones, is not cut off from nutritive action in the degree in which it might seem to be; for it is penetrated by a series of large canals, termed the *Haversian*, (after Clopton Havers, their discoverer,) which form a network in its interior, and which serve for the transmission of blood-vessels into its substance. These canals, in the long bones, run for the most part in a direction parallel to the central cavity; and they communicate with this, with the external surface, with the cancelli, and with each other, by frequent transverse

branches; so that the whole system forms an irregular network, pervading every part of the solid texture, and adapted for the establishment of vascular communications throughout. The diameter of the Haversian canals varies from 1-2500th to 1-200th of an inch, or more; the smallest being only of sufficient size to admit the passage of a single capillary vessel; whilst the largest receives a plexus of minute blood-vessels. Their average diameter may be stated at about 1-500th of an inch. They are lined by a membrane, which is continuous with that of the external surface, and which carries this inwards (so to speak) to form the lining membrane of the central cavity, and of the cancelli. On this membrane, a plexus of blood-vessels is distributed, where the size of the canal admits it;—otherwise, the tube encloses a single twig of an artery or vein. Thus we may consider the whole Osseous texture as inclosed in a membranous bag; on which blood-vessels are minutely distributed; and which is so carried into the bone by involutions and prolongations, that no part of the latter is ever far removed from a vascular surface.

Fig. 43.

Haversian Canal, seen on a longitudinal section of the compact tissue of the shaft of one of the long bones; 1, arterial canal; 2, venous canal; 3, dilatation of another venous canal.

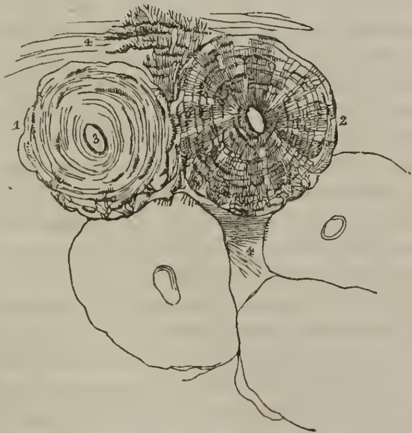
283. Between the vascular lining of the Haversian canals, and their bony walls, there is a layer of cells; as in the corresponding situation in the cancelli: so that it may be stated as a general fact, that these everywhere intervene between the blood-vessels and the osseous substance. In the adult bone, the cells which fill the remaining cavity of these canals secrete fatty matter; this is particularly evident in the case of the central cavity, where they constitute the medulla or marrow. It does not appear that these take any active part in the nutrition of the bone; indeed in the bones of Birds, the shaft is entirely hollow, and air is admitted into it from the lungs, so that its lining membrane is rendered subservient to the aëration of the blood.

284. The arrangement of the elementary parts of the osseous substance around the Haversian canals, is very interesting and beautiful. When a transverse section of a long bone is made, the open orifices of the longitudinal canals present themselves at intervals, sometimes connected by a transverse canal, where the section happens to traverse this. Around these orifices, we see the osseous matter arranged in the form of cylinders, which appears to be marked by concentric circles. Now when one of these circles is minutely examined, it is found to be made up of a series of lacunæ, analogous to those already described; these, however, are seldom or never so continuous as to

form a complete circle. The long sides of the lacunæ are directed, the one towards the Haversian canal in the centre, the other towards the circular row next beyond it. And when the course of the canaliculi is traced, it is found that these converge on the inner side towards the central canal, inosculating with those of the series next within, whilst those of the outer side pass outwards in a radiating or diverging direction, to inosculate with those of the series next external. Thus a complete communication is formed, by means of this system of radiating canaliculi, and intervening lacunæ, between the central canal, and the outermost cylindrical lamella of bony matter; and each of these lamellæ derives its nourishment from the vessels of the central canal, through the lamellæ which intervene between itself and the vascular membrane lining that tube.

285. Thus every one of the Haversian canals is the centre of a cylindrical *ossicle;* which is complete in itself, as far as its elementary structure is concerned; and which has no dependence on, or connection with, other similar ossicles. These are arranged, however, side by side, like sticks in a faggot; they are bound together by a thin cylinder of bone, on the exterior of all, which derives its nourishment from the periosteum or enveloping membrane; in like manner, the hollow bundle is lined by a similar cylinder, which surrounds the great medullary cavity, and is nourished by its vascular membrane; and the spaces that here and there intervene between the ossicles, are filled up with laminæ, which are parallel to those of the external and internal cylinders, and which seem to derive their nutriment from them (Fig. 44, 4). In this manner, the whole structure acquires great

Fig. 44.



Minute structure of bone, drawn with the microscope from nature. Magnified 300 diameters. 1. One of the Haversian canals surrounded by its concentric lamellæ. The corpuscles are seen between the lamellæ; but the calcigerous tubuli are omitted. 2. An Haversian canal with its concentric lamellæ, Purkinjean corpuscles and tubuli. 3. The area of one of the canals. 4, 4. Direction of the lamellæ of the great medullary canal. Between the lamellæ at the upper part of the figure, several very long corpuscles with their tubuli are seen. In the lower part of the figure, the outlines of three other canals are given, in order to show their form and mode of arrangement in the entire bone.

density and solidity.—The structure of the outer and inner tables of the skull, and of other thick solid layers of bone, is precisely similar;

except that the Haversian canals have no such definite directions, and form an irregular network.

286. Thus we see that each of the lamellæ of bone, surrounding an Haversian canal, or bounding the cancelli, may be regarded as a repetition of the simple bony plate, which draws its nourishment direct from the vascular membrane covering its surface, by means of its system of lacunæ and canaliculi. The membrane lining the Haversian canals, cancelli, and central medullary cavity, is an internal prolongation of that which clothes the exterior;—just as the mucous membranes, with their extensions into glandular structures, are internal prolongations of the true skin. Every Haversian canal and every cancellus are repetitions of each other in all essential particulars; their form alone being different. The central medullary canal is but an enlarged Haversian canal or cancellus. And the whole cylindrical shaft is a collection of ossicles, each of which is a miniature representation of itself, being a hollow cylinder, with a central vascular cavity.

287. The principal features of the Chemical constitution of bone are easily made evident. After all the accessory parts have been removed, and nothing remains but the real osseous texture, this may be separated, by simple processes, into its two grand constituents,—the animal basis, and the calcareous matter. The latter may be entirely dissolved away, by maceration of the bone in dilute Muriatic or Nitric acid; and a substance of cartilaginous appearance is then left, which, when submitted to the action of boiling water for a short time, is almost entirely dissolved away, and the solution forms a dense jelly on cooling. The same substance, Gelatin, may be obtained by long boiling under pressure, from previously unaltered bone; and the calcareous matter is then left in a friable condition. By submitting a bone to a heat sufficient to decompose the animal matter, without dissipating any of the earthy particles, we may obtain the whole calcareous matter *in situ;* but the slightest violence is sufficient to disintegrate it. The bones of persons long buried are often found in this condition; their form and position being retained, until they are exposed to the air, or are a little shaken; when they crumble to dust. —The proportion of the earthy matter of Bones to the animal basis may be differently stated; according as we include in our estimate of the latter, the contents of the medullary cavity, the Haversian canals, and the cancelli; or confine ourselves to that portion only of the animal matter, which is united with the calcareous element in the proper osseous tissue. According to the recent experiments of Dr. Stark,* the relative amount of the two elements, in the latter estimate, is subject to very little variation, either in the different classes of animals, or in the same species at different ages; the animal matter composing about one-third, or $33\frac{1}{3}$ per cent.; and the mineral matter two-thirds, or $66\frac{2}{3}$ per cent. The degree of hardness of bone does

* Edinburgh Medical and Surgical Journal, April, 1845.

not altogether depend, therefore, on the amount of earthy matter they may contain; for the flexible, semi-transparent, easily-divided bones of Fish contain as large an amount of animal matter, as the ivory-like leg-bones of the deer or sheep. The usual analyses of Bone, however, have been made upon the former kind of estimate; and they show that the proportion of the earthy matter to the *whole* of the animal substance contained in bone, varies much in different animals, in the same animal at different ages, and even in different parts of the same skeleton. The reason of this will be apparent, when the history of the growth of Bone has been explained; since there is a gradual filling-up of all the cavities at first occupied by fat-cells, vessels, &c., which does not cease with adult age, but which continues during the whole of life. In this manner, the bones of old persons acquire a high degree of solidity, but they become brittle in proportion to their hardness. From the same cause, the more solid bones contain a larger proportion of bone-earth than those of a spongy or cancellated texture; the temporal bone, for example, containing 63½ per cent., whilst the scapula possesses only 54 per cent. In the former of these bones, the proportion is nearly the same as that which exists in pure osseous tissue, the amount of the remaining tissues which it includes being very small, on account of the solidity of the bone: but the latter contains in its cancelli a large quantity of blood-vessels, fat-cells, &c., which swell the proportion of the animal matter from 33⅓ to 46 per cent.

288. The Lime of bones is, for the most part, in a state of Phosphate, especially among the higher animals; the remainder is a Carbonate. In Human bones, the proportion of the latter seems to be about one-sixth or one-seventh of the whole amount of bone-earth. In the bones of the lower animals, however, the proportion of Carbonate is greater; and it is curious that in callus, exostosis, and other irregular osseous formations in the higher animals, the proportion of the Carbonate should be much greater than in the sound bone. In caries, however, the proportion of the Carbonate is less than usual. The composition of the Phosphate of Lime in Bones, is somewhat peculiar; eight proportions of the base being united with three of the acid. According to Professor Graham, it is to be regarded as a compound of two tribasic phosphates; one atom of the *neutral* phosphate (in which one proportional of the acid is united with two of lime and one of water), being united with two proportionals of the *alkaline* phosphate, (in which one part of acid is united with three of the base,) together with an atom of water, which is driven off by calcination. Besides these components, some Chemists assert that a small quantity of Fluoride of calcium is present in Bone; but this is rather doubtful, since it has been shown by Dr. G. O. Rees that the solvent action upon glass, which has been supposed to be characteristic of fluoric acid, may be imitated by phosphoric acid in combination with water, which, if heated upon glass of inferior quality until it volatilizes, will act upon it with considerable energy.—Other saline matters, such as

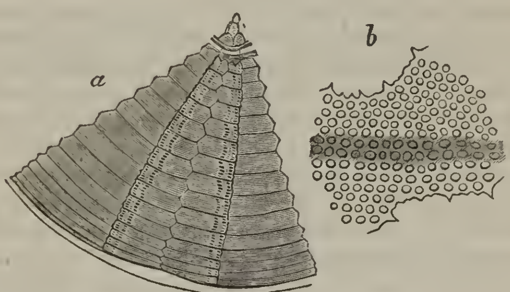
phosphate of magnesia, oxides of iron and manganese, and chloride of sodium, are found in bones in small amount.

289. The purpose of Bone in the Animal economy is obviously *mechanical*, and that only; its use being, to afford support and protection to the softer textures, and to form inflexible levers, by the action of the muscles upon which, motion may be given to the different parts of the fabric. A slight comparison of the characters and offices of the Bones of Vertebrated Animals, with the structures which form the solid skeletons of the lower classes, will afford many points of interest; and will aid in the comprehension of the purpose of the highly-elaborate structure we have been considering. Commencing with the Polypifera, or Coral-forming animals, we observe that their strong axes or sheaths are destined only to give *support* to their softer structures, and that the parts once consolidated undergo no subsequent change. It was formerly imagined, that the stony Corals were built up by the animals which form them, somewhat in the same manner as a Bee constructs its cell. But it is now fully demonstrated, that the calcareous matter (which here consists solely of the *Carbonate* of Lime) is deposited in the cells of the living tissue, by a secreting action of their own; and that the most solid mass of Coral thus has an organized basis, as complete as that of Bone. The proportion of earthy to animal matter, however, is so great in the former structures, that very little, if any, nutrient changes can take place in their tissue, when once it has become consolidated. Such changes are not, however, required. The substance thus developed by the wonderful secreting powers of the lime-secreting cells, which draw into themselves the small quantity of calcareous matter dissolved in the surrounding water, is so little disposed to undergo change, that it will maintain its solidity for centuries; and even when acted on by water or by heat, it does not undergo disintegration, for its calcareous particles arrange themselves in a new method, and become converted into a solid crystaline rock. Such rocks, the product of the metamorphosis of ancient coral-formations, make up a large proportion of the external crust of the earth. The solid stem or sheath, once consolidated, appears to undergo no further change in the living Coral-structure; for its increase takes place, not by *interstitial* but by *superficial* deposit,—that is, not by the diffusion of new matter through its whole substance, separating the parts formerly deposited from each other, but by the mere addition of particles to its surface and extremities. In this manner the growth of a solid Coral-structure may go on to an enormous extent; the surface at which the consolidating action is going on, being the only part *alive*, that is exhibiting any vital change; and all the rest of the mass being henceforth perfectly inert.

290. In the class of Echinodermata, which includes the Star-fish, Sea-Urchin, &c., we find the calcareous structure presenting a very elaborate organization; as an example of this, we shall select the shell of the Echinus, commonly known as the Sea-Egg. This shell is made

up of a number of plates, more or less regularly hexagonal, and fitted together so as completely to enclose the animal, except at two points, one of which is left open for the mouth, the other for the anus. On the surface of these plates are little tubercles, for the articulation of the spines, which serve as instruments of defence and of locomotion. The substance of the shell and of the spines is exactly alike; being a sort of areolar tissue, consolidated by the deposition of calcareous matter, and having an innumerable series of interspaces or minute cancelli, freely communicating with each other. The arrangement of this calcareous network in the spines, is most varied and elaborate; and causes thin sections of them to be among the most beautiful of all microscopic objects. The external and internal surface of each plate, in the shell of the living Echinus, is covered with a membrane,

Fig. 45.



Portion of the shell of the Echinus, showing at *a* the constituent plates with the calcified areolar tissue, of which they are composed, at *b*.

from which its nutrition is derived; this membrane dips down into the spaces between the adjacent plates; but it does not penetrate the substance of the plates themselves, nor does it transmit vessels to their interior. A similar membrane covers and encircles the spines; and it also connects these with the shell, being continuous with the membrane that envelops the latter. Thus each plate and spine is itself completely *extra-vascular;* but it is enclosed in a soft membrane, which furnishes (whether by vessels or otherwise, has not yet been ascertained), the elements of its nutrition.

291. But we do not here find any evidence of *interstitial* growth; nor is there any reason why such should be required. For the tissue of which it is composed, although of such extreme delicacy, is of great permanence, and does not exhibit the slightest tendency to decay, however long it is preserved; so that, when once consolidated, it appears to undergo no further change in the living animal. The growth of the animal, however, requires a corresponding enlargement of its enveloping shell; and this is provided for by the simple process of superficial deposit, through the subdivision of the whole shell into component plates. For by the addition of new matter *at the edge of*

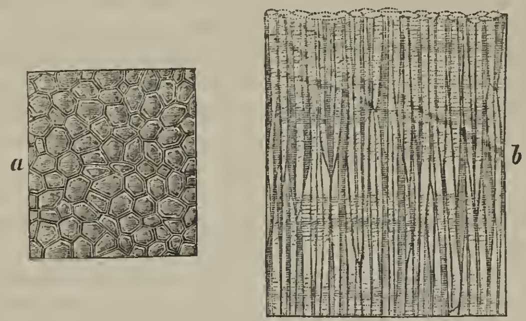
each plate, by the consolidation of a portion of the soft membrane that intervenes between the adjacent plates, the whole shell is enlarged, without losing its globular form. At the same time it is strengthened in a corresponding degree, by the consolidation of the soft tissue at the *surface* of each plate. And, in like manner, the spines are enlarged and lengthened by the progressive formation of new layers, each on the exterior of the preceding; so that a transverse section exhibits a number of concentric rings, like those of an Exogenous tree.—Thus even in the growth of this complex and elaborate structure, we recognize the principle of superficial deposit, which we shall find to be universal amongst the hard parts of the Invertebrata; notwithstanding that, at first sight, it would have appeared impossible to provide on this plan for the gradual enlargement of a globular shell, completely enclosing the animal, and therefore required to keep pace with the latter in its rate of increase.

292. Among the Mollusca, we find the body sometimes altogether destitute of solid organs of support, protection, or locomotion,—as is the case, for example, in the Slug; and the movements are feeble and the habits inert, the muscle having no fixed points for their attachment, and acting without any of the advantages of leverage. In other cases, we find the body more or less completely protected by a Shell; which is sufficiently large in some instances to cover the body completely; whilst in others, it affords only a partial investment. The plan on which this shell is formed, however, is very different from that which has just been described; being much less complex. The *Univalve* shells, or those formed in one piece, are always of a conical form; the cone being sometimes simple, as in the Limpit; in other cases being spirally coiled, as in the Snail. Now the base of this cone is open; and through this, the animal can project its movable parts. When its increasing size requires additional accommodation, it is obvious that an addition to the large end of the cone will increase its diameter and its length at the same time; so as to afford the required space, without any alteration in the form or dimensions of the older and smaller portions of the cone. This last, indeed, is frequently quitted by the animal, and remains empty; being sometimes separated from the latter portions, by one or more partitions thrown across by the animal,—as is seen especially in the Nautilus and other chambered shells.* Besides the new matter added to the mouth of the shell, a thin layer is usually formed over its whole interior surface; so that the lining of the new part is continuous with that of the old.—In the Bivalve shells, we trace this mode of increase without any difficulty; especially in such shells as that of the Oyster, in which the successive laminæ remain distinct. Each lamina is *interior* to the preceding, being formed on the living surface of the animal; but it also projects beyond it, so as to enlarge the capacity of the shell; and as the separation of the valves affords free exit to those parts of the animal, which are capable of being projected beyond the shell, there is obviously no need of any other provision to maintain the shell in

its natural form.—Thus in the shells of the Mollusca, increase takes place at the surfaces and edges only.

293. The proportion of organic and calcareous matter in Shell differs considerably in the various tribes. The former is sometimes present in such small amount, that it can scarcely be detected; and the condition of the calcareous matter then obviously approaches that of a crystaline deposit. But in other instances, the animal basis is very obvious; remaining as a thick consistent membrane, after all the calcareous matter has been dissolved away by an acid. This membrane is formed of an aggregation of cells arranged with great regularity (Fig. 46, *a*;) the cavities of which are filled with carbonate of

Fig. 46.



Prismatic cellular structure of shell of Pinna; *a*, surface of lamina; *b*, vertical section.

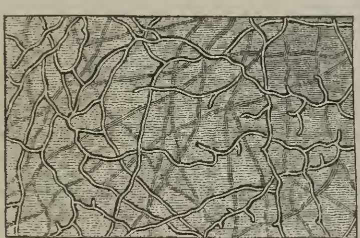
lime in a crystaline state. The form of the cells approaches the hexagonal; their diameter varies in different shells from 1-100th to 1-2800th of an inch; their thickness also is extremely variable, even in different parts of the same shell. Thus we sometimes meet with a lamina of such tenuity, as not to measure 1-100th of an inch in thickness; whilst in other instances, a single layer may have a thickness of half an inch, or even (in certain large fossil species) of an inch or more. In this case, the cells, instead of being thin flat scales like the pavement-epithelium (§ 233), are long prisms, somewhat like the cells of the cylinder-epithelium (Fig. 22), with their walls flattened against each other. The appearance which is then presented by a vertical section of them, is represented in Fig. 46, *b*. The long prismatic cells are there seen to be marked by delicate transverse striæ; and these, taken in connection with other indications, appear to show, that every such prism is in reality formed by the coalescence of a pile of flat cells, resembling those which are seen in the very thin laminæ just described; so that the thickness of the layer depends upon the number of the cellular laminæ, which have coalesced to form its component prisms. This character is of interest, as representing on a magnified scale a corresponding appearance in the enamel of human

Tooth, which we shall presently find to be formed upon the very same plan.

294. We are to regard this kind of shell-substance, therefore, as formed by the secreting action of the epithelial-cells covering the *mantle* of the animal,—which membrane, though it answers in position to the skin, has the soft, spongy, glandular character of a mucous membrane. These draw calcareous matter into their cavities, as a part of their own process of growth; this matter being supplied from the fluids of the vascular surface beneath. Now when these calcigerous cells are separated by intercellular substance, they remain distinct through the whole of their lives, and they form by their cohesion a tenacious membrane, that retains its consistency after the removal of the calcareous matter. But this is only the case in certain groups of shells, chiefly belonging to the bivalve division. When the intercellular substance is wanting, and the cells come into close contact, their partitions become indistinct on account of their extreme tenuity; and not unfrequently a *fusion* of the whole substance appears to take place, by the dissolution of the original cell-walls, so that it becomes more or less homogeneous,—traces of the original cellular structure being here and there distinguishable (§ 255).

295. Sometimes where this fusion has taken place, so as to obliterate the original cell-structure, we find the almost homogeneous substance traversed by a series of tubuli, not arranged, however, in any very definite direction, but forming an irregular network. These tubes vary in size from 1-2000th to 1-20,000th of an inch; but their general diameter, in the shells in which they most abound, is 1-4500th of an inch. In the larger tubuli, something of a bead-like structure may occasionally be seen; as if their interior were occupied by rounded granules arranged in a linear direction. Although it might be supposed that this structure is destined to convey nutrient fluid into the substance of the shell, yet there is no evidence that such is the fact; and, on the contrary, there is ample evidence, that, even in shells most copiously traversed by these tubuli, no processes of interstitial growth or renewal take place. The *permanent* character of the substance of all Shells, when once it is fully formed, is as remarkable as that of Coral; and as the adaptation of their size, to that of the animals to which they belong, is entirely effected by additions to their surfaces and edges, no interstitial deposit can have a share in producing it.

Fig. 47.



Tubular shell-structure, from Anomia.

296. Among the Articulated classes, we still find that the skeleton is altogether external, and belongs therefore to the cutaneous system; but it is formed upon a very different plan from the shells of the Mol-

lusca, being closely fitted to the body, and enveloping every part of it; consequently it must increase in capacity, with the advancing growth of the contained structures. Moreover it is destined not merely to afford support and protection to these, but to serve for the attachment of the muscles by which the body and limbs are moved; and the hard envelops of the latter serve, like the bones of the Vertebrata, as levers by which the motor powers of the muscles are more advantageously employed. Again, the hard envelops of the body and limbs are not formed of distinct plates, like those of the Echinus-shell, but are only divided by sutures at the joints, for the purpose of permitting the requisite freedom of motion. It might have been thought that here, if anywhere, a process of interstitial growth would have existed, to adapt the capacity of the envelops to the dimensions of the contained parts, as the latter increase with the growth of the animal; but, true to the general principle, that epidermic structures are not only extra-vascular, but that they undergo no change when they are once fully formed, we find that the hard envelops of Articulated animals are thrown off, or exuviated, when the contained parts require an increase of room; and that a new covering is formed from their surface, adapted to their enlarged dimensions.

297. This is well known to occur at certain intervals in Crabs, Lobsters, and other Crustacea; which thus exuviate not merely the outer shell, with the continuation of the epidermis over the eyes, but also its internal reflexion, which forms the lining of the œsophagus and stomach, and the tendinous plates by which the muscles are attached to the lining of the shell. A similar moulting may be observed to occur in some of the minute Entomostracous Crustacea of our pools, every two or three days, even after the animals seem to be full grown. During the early growth of Insects, Spiders, Centipedes, &c., a similar moult is frequently repeated at short intervals; but after these animals have attained their full growth, which is the case with Insects at their last change, no further moulting takes place, the necessity for it having ceased.—This moulting is precisely analogous to the exfoliation and new formation of the Epidermis, in Man and most other Vertebrata; differing from it only in this, that the latter is constantly taking place to a small extent, whilst the former is completely effected at certain intervals, and then ceases. We have examples of a periodical complete moult in Vertebrata, however, among Serpents and Frogs.

298. The structure of the hard envelops of Articulated animals corresponds with that of the Epidermis and its appendages in Man. The firm casings of Beetles, for example, are formed of layers of epidermic cells, united together, and having their cavities filled by a horny secretion. The densest structure is found in the calcareous shells of the Crustacea; which consist of a substance precisely analogous to the *Dentine* of Teeth (§ 311); covered on the exterior with a layer of pigment-cells. The calcareous matter consist chiefly of carbonate of lime; but traces of the phosphate are also found. The

animal basis has a firm consistent structure, resembling that of teeth. A thin vertical section shows the tubuli running nearly parallel, but with occasional undulations, from the internal surface towards the external; but no traces of the original calcigerous cells can be detected in the fully-formed shell, the process of fusion having gone so far as to obliterate them. The manner in which these tubuli are formed, will be presently considered, under the head of Dental substance.

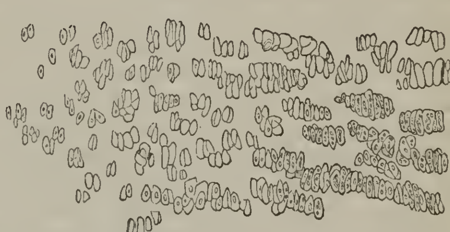
299. Now the condition of the osseous skeleton of Vertebrated animals is altogether different. It forms a part of the internal substance of their bodies; and as these grow in *every* part, and not merely by addition to this or that portion, so must the Bones also, in order to keep pace with the rest of the structure. Hence we find them so formed, that the processes of *interstitial* deposition may be continually going on in their fabric, as in that of the softer tissues; and the changes in their substance do not cease, even when they have acquired their full size. The continuance of these changes appears destined, not so much to repair any *waste* occasioned by decomposition,—for this must be very trifling in a tissue of such solidity,—as to keep the fabric in a condition, in which it may repair the injuries in its substance occasioned by accident or disease. The degree of this reparative power is proportional, as we shall presently see, to the activity of the normal changes, which are continually taking place in the bone; and is thus much greater in youth than in middle life, and greater in the vigour of manhood than in old age.

300. We shall commence the history of the development of Bone, with the period in which its condition resembles that of the permanent Cartilages. As already mentioned, there is no essential difference between the temporary and permanent Cartilages, in regard to their ultimate structure; the former, however, are more commonly traversed by vessels, especially when their mass is considerable. These vessels, however, do not pass at once from the exterior of the cartilage into its substance; but they are conveyed inwards along canals, which are lined by an extension of the perichondrium or investing membrane, and which may thus be regarded as so many involutions of the outer surface of the cartilage. These canals are especially developed at certain points, which are to be the centres of the ossifying process; of these *puncta ossificationis*, we usually find one in the centre of the shaft of a long bone, and one in each of its epiphyses; in the flat bones there is one in the middle of the surface, and one in each of the principal processes. Up to a late stage of the ossifying process, the parts which contain distinct centres are not connected by bony union, so that they fall apart by maceration; and even when they should normally unite, they sometimes remain separate,—as in the case of the Frontal bone, in which we frequently meet with a continuation of the sagittal suture down the middle, dividing it into two equal halves, which have originated in two distinct centres of ossification. It is interesting to remark that, in the two lowest classes of Vertebrata,—Fishes and Reptiles,—we find the several parts of

the osseous system presenting, in a permanent form, many of the conditions which are transitory in the higher; thus the different portions of each vertebra, the body, lateral arches, spinous and transverse processes, &c., which have their distinct centres of ossification, but which early unite in Man, remain permanently distinct in the lower Fishes; the division of the frontal bone, just adverted to, is constant amongst Reptiles; and in that class we meet with a permanent separation of the parts of the occipital and temporal bones, which, being formed from distinct centres of ossification, are at first distinct in the higher animals.

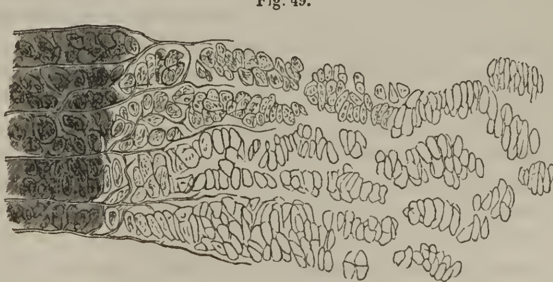
301. During the formation of the *punctum ossificationis*, and the spread of the vessels into the cartilaginous matrix, certain changes are taking place in the substance of the latter, preparatory to its conversion into bone. Instead of single isolated cells, or groups of two, three, or four, such as we have seen to be characteristic of ordinary Cartilage, (§ 267,) we find, as we approach the ossifying centre, clusters made up of a larger number, which appear to be formed by a continuance of the same multiplying process as that already described. And when we pass still nearer we see that these clusters are composed of a yet greater number of cells, which are arranged in long rows, whose direction corresponds with the longitudinal axis of the bone; these clusters are still separated by intercellular substance, and it is in this, that the ossific matter is first deposited. Thus if we separate

Fig. 48.



Section of Cartilage, near the seat of ossification; each single cell having given birth to four, five or six cells, which form clusters. These clusters become larger towards the right of the figure, and their cells more numerous and larger; their long diameter being 1-1500th of an inch.

Fig. 49.



The same cartilage at the seat of ossification; the clusters of cells are arranged in columns; the intercellular spaces between the columns being 1-3250th of an inch in breadth. To the right of the figure, osseous fibres are seen occupying the intercellular spaces at first bounding the clusters laterally, then splitting them longitudinally and encircling each separate cell. The greater opacity of the right hand border is due to a threefold cause, the increase of osseous fibres, the opacity of the contents of the cells, and the multiplication of oil-globules.

the cartilaginous and the osseous substance at this period, we find that the ends of the rows of cartilage-cells are received into deep narrow cups of bone, formed by the transformation of the intercellular substance between them. Immediately upon the ossifying surface, the nuclei, which were before closely compressed, separate considerably from one another, by the increase of material within the cells; and the nuclei themselves become larger and more transparent. These changes constitute the *first stage* of the process of ossification, which extends only to the calcification of the intercellular substance; in this stage there are no blood-vessels directly concerned. The bony lamellæ thus formed, mark out the boundaries of the cancelli and Haversian canals; which are afterwards to occupy a part of the space that is hitherto filled by the rows of cartilage-corpuscles.

302. The *second stage* of the ossifying process consists in the further transformation of the original cartilage-cells. These seem to become flattened against the osseous layers already formed, and then to become themselves consolidated by the secretion of calcareous matter into their interior,—at the same time coalescing to such a degree, that the original boundaries of the cells can no longer be traced. The consolidation, however, does not extend to the nuclei of the cells; which retain their granular condition, and, being surrounded by calcareous matter, are enclosed in cavities which take their own shape. These cavities are the subsequent *lacunæ* of the bony structure; and the branching canaliculi proceeding from them become more and more distinct, as the consolidation of the surrounding structure is completed. By the continuation of this process, one layer of cells after another is converted into bony matter; and the canals, which at first occupied the whole diameter of the cylindrical ossicles shown in Fig. 44, become gradually contracted by these deposits upon their walls. The cause of the concentric lamination of the osseous matter in each of the ossicles, of which the permanent Haversian canal is the centre, is thus apparent.

303. As the calcification of the original cartilage-cell goes on, a new substance appears in the cavities of the cancelli and canals; this is a cellular mass resembling that in which all new tissues originate; and it seems to be from this, that the vascular lining is formed, which gradually extends itself into the cancelli and canals, and which is to become from henceforth the principal source of the growth and nutrition of Bone. From the central part of this blastema, the fat-cells, constituting the medulla, must be generated. But, as already stated (§ 283), a layer of cells resembling the originals constantly intervenes between the bony walls of the canals and cancelli, and their vascular lining; apparently for the purpose of serving as the immediate agent in the nutrition of the osseous tissue.

304. When the complete Ossification of the temporary Cartilage has thus been effected, the Bone has still to be enlarged, in conformity with the increasing size of the surrounding parts; and this enlargement is due in part to *superficial*, in part to *interstitial* addition. The

superficial addition is due to the progressive formation and conversion of new cartilage at the edges and surfaces of the bone, or at the imperfectly-consolidated part that intervenes between the separately-ossified portions of the same bone. Thus it was long since proved by the experiments of Hales and Hunter, that the growth of a long bone takes place chiefly towards the extremities; for they found that, when metallic substances were inserted in the shaft of a growing bone of a young animal, the distance between them was but little altered after a long interval, whilst space between the extremities of the bone had greatly increased. And it seems that, at a later period, when the epiphyses have become completely united to the shaft, an elongation continues to take place, by the slow ossification of the articular cartilage.—Again, the bone is progressively increased in thickness, by the gradual production of new osseous matter upon its surface; this production taking place exactly upon the same plan with the original process, and involving the formation of new Haversian canals and concentric lamellæ, so that no distinction can be traced between the new and the older layers.

305. If this were the whole history of the growth of Bone, there would be no essential difference between the character of its nutrition, and that of the skeletons of the Invertebrata. But it is unquestionable, that bone is also susceptible of an interstitial change, though this is of a slow and gradual nature. The layers first deposited on the inner surface of the early cancelli, are pushed outwards by the succeeding ones, and gradually acquire an increased diameter; so that the ultimate dimensions of the cancelli and cylindrical ossicles far exceed those of the primitive cavities marked out by the calcification of the intercellular substance; and this last, also, must be greatly extended to permit such an increase. This process could not go on beyond a certain point, however, without removing the outer laminæ too far from the vascular lining of the Haversian canals; and we consequently find that the increase of the bone takes place by superficial addition, wherever this is admissible.—A very remarkable change takes place in the interior of the long bones of young animals, for the production of the central medullary cavity. At an early period, no such cavity exists, and its place is occupied by small cancelli; this is the permanent condition of the bones in most Reptiles. The cancelli gradually enlarge, however; and those within the shaft coalesce with one another until a continuous tube is formed, around which the cancelli are large, open, and irregular. At the same time, the diameter of the surrounding shaft is increasing by the process of interstitial growth just described; so that the size of the medullary cavity at last becomes greater than that of the whole shaft when its formation commenced. The aggregation of the osseous matter in a hollow cylinder, instead of a solid one, is the form most favourable to strength, as may be easily proved upon mechanical principles. The same arrangement is adopted in the arts, wherever it is desired to obtain the greatest strength with a limited amount of material.

306. The difference in the relations of the Osseous substance to the vascular network, at different ages,—accounting for the variations in the rapidity of its nutrition and reparation,—is well displayed in the effects of Madder. This substance has a peculiar affinity for Phosphate of Lime; so that when the latter is formed by precipitation in a fluid tinged with madder, it attracts colour to it in its descent, and falls to the bottom richly tinted. Now when animals are fed with this substance, it is found that their bones become tinged with it; the period required being in the inverse proportion to their age. Thus in a very young animal a single day suffices to colour the entire skeleton, for in them there is no osseous matter far from the vascular surfaces; when sections are made, however, of the bones thus tinged, it is found that the colour is confined to the immediate neighbourhood of the Haversian canals, each of which is encircled by a crimson ring. In full-grown animals, the bones are very slowly tinged; because the osseous texture is much more consolidated and less permeable to fluid than in earlier life; and because, owing to the formation of new concentric lamellæ, the outer and older ones are pushed to a greater distance from the Haversian canals, the diameter of which is contracted. In the bones of half-grown animals, a part of the bone is nearly in the perfect condition, while a part is new and easily coloured; so that the action of this substance enables us to distinguish the new from the old.

307. The Regeneration of Bone, after loss of its substance by disease or injury is extremely complete; in fact there is no other structure of so complex a nature, which is capable of being so thoroughly repaired. Although the regenerative power appears to be so much less in Vertebrated animals, than it is in the lower Invertebrata, yet it is probably not at all lower in reality,—the new structures actually formed being as complex in the one case as in the other. It is nowhere, perhaps, more remarkably manifested, than in the reformation of nearly an entire bone, when the original one has been lost by disease; all the attachments of muscles and ligaments, as well as the external form and internal structure, being ultimately found as complete in the new bone, as they originally were in that which it has replaced. Much discussion has taken place in regard to the degree, in which the different membranous structures, that surround bone and penetrate its substance, participate in its regeneration; some having supposed the periosteum to have the power of itself *forming* new bone, others attributing the same power to the membrane lining the medullary cavities. It appears next to certain, however, that new osseous tissue can only be formed in continuity with that which previously existed; and that it may be generated, by the mediation of even very minute fragments of such tissue, from *any* of the vascular membranes that happen to supply it. Thus when the portion of the shaft of a bone is entirely removed, but the periosteum is left, the space is filled up with new bony matter in the course of a few weeks; though, if the periosteum be also removed, the formation of new mat-

ter will be confined to a small addition in a conical form to the two extremities, a large interspace intervening between them. This experiment might seem to indicate, that the periosteum itself forms the bone; but the real production of new tissue,—as in cases where the periosteum has been detached by disease, and remains alive whilst the shaft dies,—is in continuity with minute spicula of the original bone, which still adhere to the periosteum.* Again, we find that in comminuted fractures, every portion of the shattered bone that remains connected with the vascular membranes, whether these be the internal or the external, becomes the centre of a new formation; and that the loss of substance is filled up the more rapidly, in proportion to the number of such centres.

308. The reparation of Bone, after disease or injury, takes place exactly upon the same plan as its first formation. A plastic or organizable exudation is first poured out from the neighbouring blood-vessels, and this forms a sort of bed or matrix, in which the subsequent processes take place. Next, a cartilaginous substance is formed, as in the embryo, by the attraction of gelatinous intercellular substance to the exterior of certain cells, and this is gradually converted into Bone, by the regular process of ossification. When the shaft of a long bone has been fractured through, and the extremities have been brought evenly together, it is found that the new matter first ossified is that which occupies the *central* portion of the deposit, and which thus connects the medullary cavities of the broken ends, forming a kind of plug that enters each. This was termed by Dupuytren, by whom it was first distinctly described, the *provisional callus*. This is usually formed in the course of five or six weeks, or less in young persons; but at that period the contiguous surfaces of the bone itself are not cemented by bony union; and the formation of the *permanent callus* occupies some months, during which the provisional callus is gradually absorbed, and the continuity of the medullary canal restored, in the same manner as it was at first established. The permanent callus has all the characters of true bone.

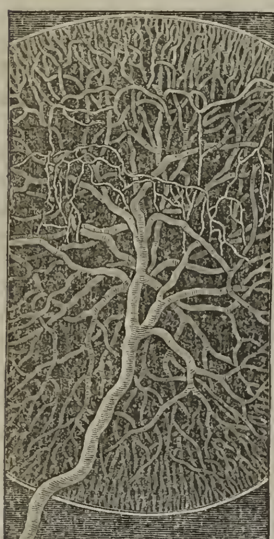
309. The most extensive reparation is seen, when the shaft of a long bone is destroyed by disease. If violent inflammation occur in its tissue, the *death* of the fabric is frequently the consequence,—apparently through the blocking-up of the canals with the products of the inflammatory action, and the consequent cessation of the supply of nutriment. It is not often that the whole thickness of the bone becomes necrosed at once; more commonly this result is confined to its outer or its inner layers. When this is the case, the new formation takes place from the part that remains sound; the external layers, which receive their vascular supply from the periosteum and from the Haversian canals continued inwards from it, throwing out new matter on their interior, which is gradually converted into bone; whilst the internal layers, if *they* should be the parts remaining uninjured, do

* See Mr. J. Goodsir on the Reproduction of Bone, in his Anatomical and Pathological Researches.

the same on their exterior, deriving their materials from the medullary membrane and its prolongations into their Haversian canals. But it sometimes happens that the whole shaft suffers necrosis; and as the medullary membrane and the entire system of Haversian canals have lost their vitality, reparation can only take place from the splinters of bone which remain attached to the periosteum, and from the living bone at the two extremities. This is consequently a very slow process; more especially as the epiphyses, having been originally formed as distinct parts from the shaft, do not seem able to contribute much to the regeneration of the latter.*

310. We next proceed to the *Teeth*, which are organs of mechanical attrition, developed in the first part of the alimentary canal, for the purpose of comminuting the food conveyed into it. Their place of origin is altogether different from that of bone, as they commence in little papillary elevations of the mucous membrane covering the jaw; but the substance from which they are formed is the same primitive cellular tissue, as that in which Cartilage itself originates. We may best understand the structure and development of the Teeth in Man, by first inquiring into the characters presented by those of some of the lower animals, and the history of their evolution. In the fœtal Shark, the first appearance of the tooth is in the form of a minute papilla on the mucous membrane covering the jaws; the substance of this papilla is composed of spherical cells, which are imbedded in a kind of gelatinous substance resembling that of incipient cartilage; whilst its exterior is composed of a dense, structureless, pellucid membrane. The cellular mass is not at first permeated by vessels; but a small arterial branch is distributed to each papilla, and spreads out into a tuft of capillaries at its base (Fig. 50). The papilla gradually enlarges, by the formation of new cells at the part immediately adjacent to the blood-vessels, which supply the material requisite for their development; and when it has acquired its full size, the process of *calcification* takes place, by which it is converted into Dentine,—the substance most characteristic of teeth.

Fig. 50.



Vessels of Dental Papilla.

311. This *Dentine*, which in the Elephant's tusk is known as Ivory,

* For many parts of the foregoing account of the structure and development of Bone, the Author is indebted to the Chapter on that subject in Messrs. Todd and Bowman's Physiological Anatomy, as well as to the papers of Mr. Goodsir already referred to.

is a firm substance, in which mineral matter predominates to a greater extent than in bone; but which still has a definite animal basis, that retains its form when the calcareous matter has been removed by maceration in acid. In every 100 parts, the animal matter forms about 28; and of the mineral portion phosphate of lime constitutes about $64\frac{1}{3}$ parts, carbonate of lime $5\frac{1}{3}$ parts, and phosphates of magnesia and soda, with chloride of sodium, about $2\frac{1}{3}$ parts. When it is fractured, it seems to possess a fibrous appearance; the fibres radiating from the centre of the tooth towards its circumference. But when a thin section of it is submitted to the microscope, it is seen that this fibrous appearance is due to a peculiar structure in the dentine, which the unaided eye cannot discover. The dentinal substance is itself very transparent; but it is traversed by minute tubuli, which appear as dark lines, generally in very close approximation, running from the internal portion of the tooth towards the surface, and exhibiting numerous minute undulations, and sometimes more decided curvatures, in their course. They occasionally divide into two branches, which continue to run at a little distance from one another in the same direction; and they also frequently give off small lateral branches, which again send off smaller ones. In some animals, the tubuli may be traced at their extremities into minute cells, or cavities, analogous to the lacunæ of bone; and the lateral branchlets occasionally terminate in such cavities, which are called the intertubular cells. The diameter of the tubuli at their largest part averages 1-10,000th of an inch; their smallest branches are immeasurably fine. It is impossible that even the largest of them can receive blood, as their diameter is far less than that of the blood-discs; but it is probable that, like the canaliculi of bone, they may absorb nutrient matter from the vascular surface, with which their internal extremities are in relation.

Fig. 51.

Oblique section of Dentine of human tooth, highly magnified, showing the calcigerous tubuli, and the outlines of the original cells.

312. In the Teeth of Man and of most Mammalia, we find the central portion hollow; and lined, in the living tooth, by a vascular membrane. This cavity, with its vascular wall, is analogous to an enlarged cancellus or Haversian canal of Bone; and, as we shall presently see, it is formed in a similar manner. Upon the walls of the cavity, all the tubuli open; and they radiate from this towards the surface of the upper part of the tooth, as shown in the accompanying figure. The central cavity is continued as a canal through each fang or root; and the dentinal tubes in like manner radiate from this, towards the surface of the fang.—In the teeth of many of the lower animals, however, we find a network of canals extending through the substance of the tooth, instead of a single cavity; and these canals are

13

frequently continuous with the Haversian canals of the subjacent bone, so that the analogy between the two is complete. From each canal the dentinal tubuli radiate, just in the manner of the canaliculi of bone (§ 279); and thus we may regard a tooth of this kind as repeating, in each of the parts surrounding one of these canals, the structure of the human tooth.

313. The process by which the cellular mass, or *pulp*, of the dental papilla, becomes converted into the dentine of the perfect tooth, is thus described by Prof. Owen, from his investigations into the history of the Shark's dentition.—The pulp becomes vascular, by the extension of the capillary network into its substance; the vessels are also accompanied by fine branches of nerves. The cells arrange themselves in lines, radiating from the centre to the circumference of the pulp; and they become somewhat elongated in that direction. A series of changes takes place in the nuclei of the cells, consisting chiefly in their elongation and subdivision; so that they form a series of parallel lines within each cell. The subdivided and elongated nuclei become attached, by their extremities, to the corresponding nuclei of the cells in advance, and the attached extremities form continuous lines; so that in each row or file of cells, extending from the inner part to the circumference of the pulp, there are several dark lines, apparently continuous, which are formed by rows of granules (or perhaps incipient cells) thus derived from the once single and rounded nuclei of the parent-cells. During the same time, the walls of the adjacent cells come into closer proximity, to the exclusion of the gelatinous matter, that originally intervened between them; and they secrete calcareous matter, derived from the blood, into their own cavities. The cells thus become completely filled with that material (probably combined with gelatin, as in bone), excepting in the part occupied by the rows of granules, which are thus left unconsolidated; and which, when the granules disappear at a subsequent period, remain as the dentinal tubes. This consolidation first takes place on the exterior of the pulp; and the calcifying process gradually extends itself inwards, causing the blood-vessels to retreat, as it were, towards the centre, where an unconsolidated portion usually remains.

314. Thus the substance of the outer portion of the pulp is actually *converted* into dentine, and does not form it by a process of *excretion*, as was formerly supposed. In general, the coalescence of the original cells is so complete, that their boundaries altogether disappear, and the substance that intervenes between the tubuli seems quite homogeneous; but distinct traces of the original division into cells may often be met with, in the dentine of Man (Fig. 50), as well as in that of other animals; which satisfactorily confirms what has been just stated, as to the mode of its formation. Although in the most characteristic form of Dentine, no blood-vessels exist, yet there are certain species, both among Mammals, Reptiles, and Fishes, in which the Dentine is traversed by cylindrical prolongations of the central cavity, conveying blood-vessels into its substance; and the presence of these

medullary canals thus gives to the Dentine a vascular character; and thus increases its resemblance to bone.—The central portion of the pulp is sometimes converted into a substance still more nearly resembling bone, having its stellate lacunæ as well as its vascular canals. This change is normal or regular in certain animals, as in the extinct Iguanodon and Icthosaurus, and in the Cachalot or Sperm-whale; and the ossified pulp bears a close resemblance to the bones of the respective animals, although it is not formed in continuity with them. A similar change occurs in the Human tooth;—sometimes, it would appear, rapidly, as the result of disease; but in general more slowly, increasing gradually with the advance of age.

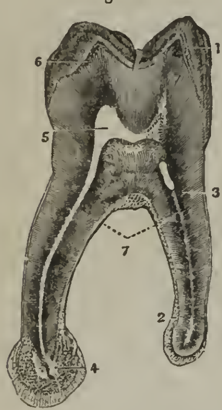
315. It is not easy to ascertain the amount of nutritive change that takes place in the substance of Dentine, when it is once fully formed. When young animals are fed with colouring-matter, it is found to tinge their teeth, as well as their bones; and if the tooth be in process of rapid formation at the time of the experiment, the progressive calcification of the pulp, from without inwards, is marked by a series of concentric lines. Even in the adult, some tinge will result from a prolonged use of this substance; and it has been noticed that the teeth of persons, who have long suffered from Jaundice, sometimes acquire a tinge of bile. These facts show that, even after the complete consolidation of the Dentine, it is still pervious to fluids: and that in this manner it may draw into itself, from the vascular lining of the pulp-cavity, a substance capable of repairing its structure, is proved by the circumstance, that a new layer of hard matter is occasionally thrown out upon a surface which has been laid bare by caries.

316. In those simple teeth which consist solely of Dentine, the mode of production already described,—that of the consolidation of a papilla upon the mucous membrane of the mouth,—is all which is requisite. When the formation of the tooth itself is complete, it may remain attached only to the mucous membrane, which is the case in the Shark, or it may grow downwards, by the addition of new dental structure at its base, until it comes in contact with the bone of the jaw. Where it is only attached to the mucous membrane, as in the Shark, it is very liable to be torn away; but a new tooth, formed from a distinct papilla, is ready to replace it; and this process is continually repeated, the development of new papillæ being apparently unlimited. On the other hand, where the root of the tooth comes in contact with the jaw, it may completely coalesce with it, which is the case in many Fishes, the Haversian canals of the bone being continued as medullary canals into the dentine; or it may send long spreading roots into the bone, which are united to it at their extremities. In the classes of Fishes and Reptiles (with scarcely any exceptions) the teeth are by no means permanent, as among Mammalia; but new teeth are continually succeeding the old ones. The mode in which these teeth originate, by small buds from the capsules of the preceding, will be understood when the *capsular* development of all the higher forms of the dental apparatus has been described.

317. It is obvious that there is no provision, in the simple calcification of the dental papilla, for any variations or density, other than those which may result from the different degrees of hardness in the substance of the dentine itself. Now in the teeth of Man and most other Mammals, and in those of many Reptiles and some Fishes, we find two other substances, one of them harder, and the other softer, than Dentine; the former is termed *Enamel;* and the latter *Cementum* or *Crusta petrosa.* For the development of these, a peculiar modification of the apparatus is requisite.

318. The *Enamel* is composed of long prismatic cells, exactly resembling those of the prismatic shell-substance formerly described, but on a far more minute scale; the diameter of the cells not being more, in Man, than 1-5600th of an inch. The length of the prisms corresponds with the thickness of the layer of enamel; and the two surfaces of this layer present the ends of the prisms, which are usually more or less regularly hexagonal. The quantity of animal matter in the tooth of the adult is extremely minute,—not above two parts in 100; and it is only at a very early age, that the true character of the animal structure can be distinctly seen. The course of the prismatic cells is more or less wavy; and they are marked by numerous transverse striæ, resembling those of the prismatic shell-substance, and probably originating in the same cause,—the coalescence of a line of shorter cells, to form the lengthened prism. No trace of tubuli or of blood-vessels is to be found in the completely formed Enamel of higher animals; but in the teeth of certain Fishes, it is penetrated by calcigerous tubes, which enter its substance from the exterior, and ramify and subdivide like those of the dentine. Of the 98 parts of mineral matter in the enamel, $88\frac{1}{2}$ consist (according to Berzelius) of phosphate of lime, 8 of carbonate of lime, and $1\frac{1}{2}$ of phosphate of magnesia. In density and resisting power, the Enamel far surpasses any other organized tissue, and approaches some of the hardest of mineral substances. In Man, and in Carnivorous animals, it covers the crown of the tooth only, with a simple cap or superficial layer of tolerably uniform thickness (Fig. 52, 1), which follows the surface of dentine in all its inequalities; and its component prisms are directed at right angles to that surface, their inner extremities resting in slight but regular depressions on the exterior of the dentine. In the teeth of many Herbivorous animals, however, the Enamel forms (with the Cementum) a series of vertical plates, which dip down (as it were) into the substance of the dentine,

Fig. 52.



Vertical section of human molar tooth;—1, enamel; 2, cementum or crusta petrosa; 3, dentine or ivory; 4. osseous excrescence, arising from hypertrophy of cementum; 5, cavity; 6, osseous cells at outer part of dentine.

and present their edges alternately with it, at the grinding surface of the tooth; and there is in such teeth no continuous layer of dentine over the crown. The purpose of this arrangement is evidently to provide, by the unequal *wear* of these three substances,—of which the Enamel is the hardest and the Cementum the softest,—for the constant maintenance of a rough surface, adapted to triturate the tough vegetable substances on which these animals feed.—The Enamel is the least constant of the Dental tissues. It is more frequently absent than present in the teeth of the class of Fishes; it is wanting in the entire order of Ophidia (Serpents) among existing Reptiles; and it forms no part of the teeth of the Edentata (Sloths, &c.) and Cetacea (Whales) amongst Mammals.

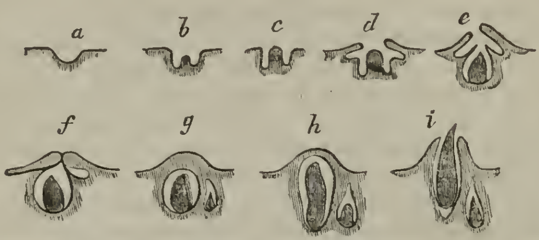
319. The *Cementum*, or *Crusta Petrosa*, has the characters of true bone; possessing its distinctive stellate lacunæ and radiating canaliculi. Where it exists in small amount, we do not find it traversed by medullary canals; but, like Dentine, it is occasionally furnished with them, and thus resembles Bone in every particular. These medullary canals enter its substance from the exterior of the tooth; and consequently pass towards those, which radiate from the central cavity towards the surface of the dentine, where *it* possesses a similar vascularity,—as was remarkably the case in the teeth of the extinct Megatherium.—In the Human tooth, however, the Cementum has no such vascularity. It forms a thin layer, which envelops the root of the tooth, commencing near the termination of the capping of Enamel (Fig. 52, 2). This layer is very subject to have its thickness increased, especially at the extremity of the fangs, by hypertrophy, resulting from inflammation; and sometimes large exostoses are thus formed (Fig. 52, 4), which very much increase the difficulty of extracting the tooth. When the tooth is first developed, the Cementum envelops its crown, as well as its body and root; but the layer is very thin where it covers the Enamel, and being soft, it is soon worn away by use. In the teeth of many Herbivorous Mammals, it dips down with the Enamel to form the vertical plates of the interior of the tooth; and in the teeth of the Edentata as well as of many Reptiles and Fishes, it forms a thick continuous envelop over the whole of the surface, until worn away at the crown.

320. The development of these additional structures is provided for by the enclosure of the primitive papilla, from which the Dentine is formed, within a Capsule, which, at one period, completely covers it in: between the inner surface of the capsule, and the outer surface of the dentinal papilla, a sort of epithelium is developed, by the calcification of which, the Enamel is formed; and the Cementum is generated by the conversion of the capsule itself into a bony substance.—The processes by which this capsular investment is produced, and the tooth completed and evolved, will now be briefly described, as they occur in the Human fœtus.

321. The dental papillæ begin to make their appearance, at about the *seventh* week of embryonic life, upon the mucous membrane

covering the bottom of a deep narrow groove (Fig. 53, *a*), that runs along the edge of the jaw (Fig. 53, *b*); and during the *tenth* week, processes from the sides of this "primitive dental groove," particu-

Fig. 53.



Successive stages of the development of the deciduous or temporary teeth, and of the origin of the sacs of the permanent set.

larly the external one, begin to approach one another, so as to divide it, by their meeting, into a series of open follicles, at the bottom of which the papillæ may still be seen. At the *thirteenth* week, all the follicles being completed, the papillæ, which were at first round blunt masses of cells, begin to assume forms more characteristic of the teeth which are to be developed from them; and by their rapid growth, they protrude from the mouths of the follicles (Fig. 53, *c*). At the same time, the edges of the follicles are lengthened into little valve-like processes, or *opercula*, which are destined to meet and form covers to the follicles (Fig. 53, *d*). There are two of these opercula in the Incisive follicles, three for the Canines, and four or five for the Molars. And by the fourteenth week, the two lips of the dental groove meet over the mouths of the follicles, so as completely to enclose each papilla in a distinct capsule (Fig. 53, *e*). At this period, before the calcification of the primitive pulps commences, a provision is made for the production of the second or permanent molars; whose capsules originate in buds or offsets from the upper part of the capsules of the temporary or milk-teeth (Fig. 53, *f*). These offsets are in the condition of open follicles, communicating with the cavity of the primitive tooth; but they are gradually closed in, and detached altogether from the capsules of the milk-teeth (Fig. 53, *g*, *h*, *i*).

322. Soon after the closure of the follicles of the Milk-teeth, the conversion of the cells of the original papilla into Dentine commences, according to the method already described (§ 313). Whilst this is going on, the follicles increase in size, so that a considerable space is left between their inner walls and the surface of the dental papillæ; which space is filled up with a gelatinous granular matter, the Enamel-pulp. The portion of this which is converted into enamel, however, is very small; being only a thin layer, which is left on the inner surface of the capsule after the remainder has disappeared. The interior of the dental sac, at the time when the conversion-process has reached the base of the dentinal pulp, is in the villous and vascular condition

of a Mucous membrane,—which indeed it really is, having been, as we have seen, once continuous with the lining of the mouth; and the layer of prismatic cells which covers its free surface, and by the calcification of which the enamel is produced, may be regarded as an epithelium.—The completion of the Enamel, and the ossification of the capsule so as to form the Cementum, take place at a subsequent period.

323. We have thus seen that the history of the first development of the human teeth may be divided into three stages, the *papillary*, the *follicular*, and the *saccular*. The papillary corresponds precisely with the complete mode of dental development in the Shark and other Fish,—as already mentioned. The follicular, which commences with the enclosure of the papilla in open follicles, and terminates when the papillæ are completely hidden by the closure of the mouths of those follicles, has also its permanent representation in the development of the teeth of many Reptiles and Fishes; the primitive papillæ of which, though enclosed in follicles, are never covered in at the summit, and thus free themselves from their envelops by simply growing upwards through their open mouths. But in Man, in all other animals which agree with him in going on to the saccular stage, there must also be an *eruptive* stage, which consists in the bursting-forth of the tooth from the enclosing capsule; the summit of the tooth being carried against the lid of the sac, by the growth of its root (Fig. 53, *h*). By the continuance of the same growth, the teeth are caused to penetrate the gum, and are gradually raised above its surface (Fig. 53, *i*).

324. All the permanent teeth, which are destined to replace the temporary set, originate, as already stated, in buds or offsets from the capsules of the latter. But behind the last temporary molars, which are replaced by the permanent bicuspids, three permanent molars are to be developed, on each side of either jaw. The *first* of these is formed on precisely the same plan with the milk-teeth; but is not completed until a later period. The capsule of the *second* is formed at a later period from that of the first, by a process of budding exactly analogous to that by which the other permanent capsules are formed from the corresponding temporary; and at a still later period, the capsule of the *third* permanent molar is formed as a bud from that of the second. The evolution of this molar does not usually take place until the system has acquired its full development; and the process of budding then ceases in Man,—being limited to a single act of reproduction in the case of the ordinary Milk-teeth, and to a double one in that of the first permanent Molar. In many animals of the lower classes, however, the process goes on through the whole of life without any limit; the newly-formed teeth, however, usually replacing those of the previous set, and not being developed at their sides like the second and third permanent molars of Man.

325. By a process of this kind, the continual renewal of the Teeth takes place in those Reptiles and Fishes, whose dentition goes on to

the saccular stage; in those at which it stops at the papillary, the successive teeth are formed from new and independent papillæ. The only exception to the rule, that no Reptiles or Fishes have permanent teeth, is found in the curious Dicynodon; an extinct Reptile which had two large tusks growing from *persistent* pulps, like those of the Elephant, the front teeth of the Rodentia, and the grinders of the Edentata. In such teeth, the base of the pulp remains unconverted, and a new development of cells is continually taking place in that situation; these new cells are in their turn converted into dentine, in continuity with that previously formed; and thus the tooth or tusk is continually lengthening at its base, in a degree which compensates for its usual wear at its summit. If anything should prevent that wear, —as when the opposite tooth has been broken off,—there is an absolute increase in the length of the tooth, from the continued growth at its base; which may become a source of great inconvenience to the animal. There is nothing, in the human subject, at all analogous to this mode of development from persistent pulps; the process being checked by the closure of the root around the base of the pulp, which obstructs the supply of blood it receives. The analogy between the continued succession of teeth in the lower Vertebrata, by the gemmiparous reproduction of their capsules, and the development of the capsules of the permanent teeth of Man from those of the temporary set, is made further evident by the fact, that a *third* set occasionally makes its appearance in persons advanced in life; the development of which would not be intelligible, if we could not refer it to the continuance of the same process in the other capsules, as that which regularly takes place to a limited extent in the permanent molars of Man, and which goes on without limit through the whole lives of the lower Vertebrata.

326. The following table shows the usual periods at which the different teeth of the two sets first show themselves above the gum. It must be borne in mind, however, that these periods are subject to very great variation; and that the average alone can therefore be expressed.

Temporary or Deciduous Teeth.

	Months.
Central Incisors	7
Lateral Incisors	8—10
Anterior Molars	12—13
Canines	14—20
Posterior Molars	18—36

Permanent Teeth.

	Years.
First Molar	$6\frac{1}{2}$ to 7
Central Incisors	7 — 8
Lateral Incisors	8 — 9
First Bicuspid	9 —10
Second Bicuspid	10 —11
Canines	12 —$12\frac{1}{2}$
Second Molars	$12\frac{1}{2}$—14
Third Molars	16 —30

327. We have seen that the Teeth are formed, in the first instance, upon the *surface* of the Mucous membrane of the mouth; and con-

sequently they really form a part of the *external* or dermo-skeleton, and not of the *internal* or osseous skeleton. They correspond, therefore, with the external skeletons of the Invertebrata; and thus the analogy which has been pointed out, between the enamel of teeth and the prismatic cellular substance of the shells of Mollusca, and between the dentine and the shells of the higher Crustacea, holds good also in regard to the situation of these structures. Although the teeth are the only ossified portions of the dermo-skeleton in Man, we find the body partially or completely enclosed in an armour of bony scales or plates, in certain Mammalia, Reptiles, and Fishes; and in some species of the last-named class, which have now ceased to exist, the scales seem to have had the texture of Enamel.

328. In connection with the teeth, the structure and development of the *Hair* may be described; this substance being generated very much in the same manner as dentine,—by the conversion of a pulp enclosed in a follicle; though the product of the transformation is different. The Hair-follicle is formed by the inversion of the Skin, as the Tooth-follicle is by an inversion of the Mucous membrane; and it is lined by a continuation of the epidermis. From the bottom of the follicle, a sort of papilla rises up, formed of cells; the exterior of this, which is the densest part, is known as the *bulb;* whilst the softer interior is termed the *pulp*. The follicle itself is extremely vascular; and even the bulb is reddened by a minute injection; though no distinct vessels can be traced into it.—It has been imagined until recently, that the Hair, like the other extra-vascular tissues, is a mere product of secretion; its material, which is chiefly horny matter of the same composition with that of the epidermis and its other appendages (§ 227), being elaborated from the surface of the pulp. This, however, proves to be a very erroneous account of it; as is shown by the results of recent microscopic inquiries into its structure. Although the Hairs of different animals vary considerably in the appearances they present, we may generally distinguish in them two elementary parts;—a *cortical* or investing substance, of a fibrous horny texture; and a *medullary* or pith-like substance, occupying the interior. In some instances, however, there is scarcely any medullary substance to be traced; whilst in other cases (as in the hair of the Musk-Deer) the entire hair seems made up of it.

329. The fullest development of both substances is to be found in the spiny hairs of the Hedgehog, and in the quills of the Porcupine, which are but hairs on a magnified scale. The cortical substance forms a dense horny tube, to which the firmness of the structure seems chiefly due; whilst the medullary substance is composed of an aggregation of very large cells, which seem not to possess any fluid contents in the part of the hair that is completely formed. In the hair of the Mouse and other small Rodents, we see the horny tube crossed at intervals by partitions, which are sometimes complete, sometimes only partial; these are the walls of the single or double line of cells, of which the medullary substance is made up. In the Human hair,

the chief part is composed of a tube of a horny substance, corresponding with the cortical sheath of the hairs of other animals; this is fibrous in its texture, as may be shown by crushing the hair, after it has been softened by maceration in dilute acid; and the outlines of the fibres are indicated by very delicate longitudinal striæ, which may be traced through its whole thickness. This fibrous structure sometimes makes up the whole thickness of the hair; but there is usually a central medulla, composed of colourless cells, with which pigment-cells are mingled. The hair is invested by a series of very minute scales, resembling those of the epidermis, but much smaller; these are arranged in rows, like tiles upon a roof, and their edges form delicate lines upon the surface of the hair, which are sometimes transverse, sometimes oblique, sometimes apparently spiral. The colouring matter of the hair appears to be related to Hæmatosine; it is bleached by Chlorine; and its hue seems dependent in part upon the presence of iron, which is found in larger proportion in dark than in light hair.

330. The fibres of the cortical substance are probably cells, which have become elongated by the process formerly described, and which have at the same time secreted horny matter into their interior. This change is continually going on in the *bulb* of the hair, at the base of the part previously completed; and by the progressive formation of new cells in the bulb, a constant growth of the cortical substance is provided for. The mode in which the medullary substance is generated, does not seem very clear; but it probably consists of the contents of the cells of the *pulp*, in which a continuous growth goes on, at the same rate with that of the bulb. Thus the Hair is constantly undergoing elongation by the addition of new substance at its base; precisely in the same manner as the teeth of certain Mammals grow from persistent pulps. The part once formed usually undergoes no subsequent alteration; but there is evidence that it *may* be affected by changes at its base, the effect of which is propagated along its whole extent. Thus it is well known that cases are not unfrequent, in which, under the influence of strong mental emotion, the whole of the hair has been turned to gray, or even to a silvery white, in the course of a single night;—a change which can scarcely be accounted for in any other way, than by supposing that a fluid, capable of chemically affecting the colour, is secreted at the base of the hair, and transmitted by imbibition through the medullary substance to the opposite extremity. The knowledge of the organized structure of hair, enables us better to understand some of the effects of disease; and especially of that peculiar affection termed Plica Polonica. The hair of individuals suffering from it is disposed to split into fibres, often at a considerable distance from the roots, and to exude a glutinous substance; and these two causes unite in occasioning that peculiar *matting* of the hair, which has given origin to the name of the disease. In the hair thus affected, there is evidently a power of transmitting fluid absorbed at the roots; and it is said that even

blood exudes from the stumps, when the hairs are cut off close to the skin.

6. *Of Cells coalesced into Tubes, with Secondary Deposit.*

331. Most of the tissues which have been hitherto described, differ in no essential particulars from those of Plants; the chief departure from the forms presented by the latter, being in the Fibrous tissues, which, as already observed, are introduced for the sake of facilitating the movements of the several parts of the structure, one upon the other. The various *cellular* tissues find their exact representatives in those of the Vegetable fabric; and the denser parts of the Animal, such as Bone, Cartilage, &c., are represented by the solid substances formed by the Plant in the heart-wood of the stem, the stone of fruits, &c.,—these substances acquiring their density in precisely the same manner with the Osseous tissues, by the secreting action of their own cells, which draw a solidifying material from the general circulating fluid. But we now come to two tissues of the highest importance in the Animal fabric; the presence of which is, indeed, its distinguishing characteristic. These are the *Muscular*, and the *Nervous* tissues. The former is the one, by which all the sensible *movements* of the body are effected; and the latter serves as the instrument, by which *sensations* are received, and by which the *will* excites the muscles to action,—besides serving as the medium for other operations, in which motion is produced, without the intervention of either sensation or will. These tissues, with the apparatus of bones and joints on which the muscles act, constitute the purely *animal* portion of the fabric; and if a being could be constructed, in which they should be capable of continued activity without any other assistance, it would be in all essential particulars an Animal. But, as we shall presently see, the plans on which these tissues are formed, in fact the very conditions of their existence and activity, are such, that they require constant *nutrition* and *re-formation;* so that the Animal cannot exist, without an apparatus for preparing, circulating, and maintaining in constant purity, a fluid, by which nutrient operations may be effected, and which shall also be the means of carrying off the products of the *waste* consequent upon the action of those tissues. This apparatus constitutes the Vegetative portion of the frame; the elementary parts concerned in which have been already noticed.

332. When we examine an ordinary Muscle with the naked eye, we observe that it is made up of a number of *fasciculi* or bundles of fibres; which are arranged side by side with great regularity, in the direction in which the muscle is to act; and which are united by areolar tissue. These fasciculi may be separated into smaller parts, which appear like simple fibres; but when these are examined by the microscope, they are found to be themselves fasciculi composed of minuter fibres bound together by delicate filaments of areolar tissue. By carefully separating these, we may obtain the ultimate *Muscular*

Fibre. This fibre exists under two forms, the *striated* and the *non-striated;* the former makes up the whole substance of those muscles, over which the will has control, or which are usually called into operation through the nerves; whilst the latter exists in the muscles which the will cannot influence, and which are excited to contraction by stimuli that act *directly* upon them. The muscles of the former class minister to the *animal* functions; those of the latter to the functions of *organic* or *vegetative* life. The appearance presented by the striated fibres of voluntary muscles, is shown in Fig. 54; that of the non-striated fibres of the muscles of organic life, in Fig. 55.

Fig. 54.

Fasciculus of striated Muscular Fibre, showing at *a* the transverse striæ, and at *b*, the longitudinal striæ, more distinctly.

333. When the fibre of voluntary muscle is more closely examined, it is seen to consist of a delicate tubular sheath, quite distinct on the one hand from the areolar tissue which binds the fibres into fasciculi, and equally distinct from the internal substance of the fibre. This cannot always be brought into view, on account of its transparency; it becomes most evident, when (as occasionally happens) the contents of the fibre are separated transversely by the drawing apart of its extremities, without the rupture of the sheath; but it may also be sometimes seen rising up in wrinkles upon the surface of the fibre, when the latter is in a state of contraction. This membranous tube, which has been termed the *Myolemma*, has nothing to do with the production of the striæ; these being due, as will be presently shown, to the peculiar arrangement of its contents. It is not perforated either by nerves or capillary vessels; and forms, in fact, a complete barrier between the real elements of Muscular structure, and the surrounding parts. That it has no share in the contraction of the fibre, is evident from the fact just mentioned, in regard to its wrinkled aspect when the fibre is shortened.

Fig. 55.

Non-striated Muscular Fibre; at *b*, in its natural state; at *a*, showing the nuclei after the action of acetic acid.

334. Although Muscular fibres are commonly described as cylindrical in form, yet they are in reality rather polygonal, their sides being flattened against those of the adjoining fibres. In some instances, the angles are sharp and decided; in others they are rounded off, so as to leave spaces between the contiguous fibres, for the passage of vessels. In Insects, the fibres often present the form of flattened bands, on which the transverse striæ are very beautifully marked. The size of the fibres is subject to great

variation, not merely in different classes of animals, but in different species, in different sexes of the same species, and even in different parts of the same muscle. Thus Mr. Bowman estimates the *average* diameter of the fibres in the Human *male* at 1-352d of an inch; the *largest* being 1-192d, and the *smallest* 1-507th. In the *female*, he found the *average* to be 1-454th of an inch; whilst the largest was 1-384th, and the smallest 1-615th. The average size of the Muscular fibre is greater among Reptiles and Fishes, than in other Vertebrata; but on the other hand the extremes are much wider. Thus its dimensions vary in the Frog from 1-100th to 1-1000th of an inch; and in the Skate from 1-65th to 1-300th.

335. When the striated Muscular Fibre is examined still more closely, it is found to contain an assemblage of very minute elements, which appear to be flattened disk-like cells, of very uniform size. These primitive particles are adherent to each other both by their flat surfaces, and by their edges. The former adhesion is usually the most powerful; and causes the substance of the fibre, when it is broken up, to present itself in the form of delicate *fibrillæ*, each of which is composed of a single *row* of the primitive particles (Fig. 56). On the other hand, the lateral adhesion is sometimes the stronger; and causes the fibre to break across into *disks*, each of which is composed of a *layer* of the primitive particles (Fig. 57). That the fibre is a solid collection of these elementary parts, and not hollow in the centre, as some have supposed, is shown by making a thin transverse section of a fasciculus (Fig. 58); by which also the polygonal form of the fibre is made apparent.

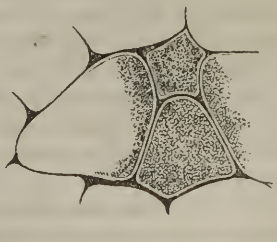
Fig. 56.

Striated Muscular fibre separating into fibrillæ, from a preparation by Mr. Lealand.

Fig. 57.

An ultimate fibre, in which the transverse splitting into disks, in the direction of the striation of the ultimate fibrils, is seen.

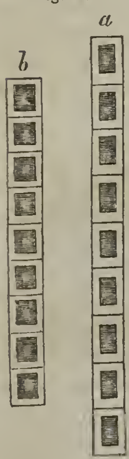
Fig. 58.



Transverse section of ultimate fibres of the biceps. In this figure the polygonal form of the fibres is seen, and their composition of ultimate fibrils.

336. When the fibrillæ are separately examined, under a high magnifying power, they are seen to present a cylindrical or slightly-beaded form, and to be made up of a linear aggregation of distinct cells. We observe the same alternation of light and dark spaces, as when the fibrillæ are united into fibres or into small bundles; but it may be distinctly seen, that each light space is divided by a transverse line; and that there is a pellucid border at the *sides* of the dark spaces, as well as between their contiguous extremities (Fig. 59). This pellucid border seems to be the cell-wall; the dark space enclosed by it (which is usually bright in the centre) being the cavity of the cell, which is filled with a highly-refracting substance. When the fibril is in a state of relaxation, as seen at *a*, the diameter of the cells is greatest in the longitudinal direction: but when it is contracted, the fibril increases in diameter as it diminishes in length; so that the transverse diameter of each cell becomes equal to the longitudinal diameter, as seen at *b;* or even exceeds it. Thus the act of Muscular contraction seems to consist in a change of form in the cells of the ultimate fibrillæ, consequent upon an attraction between the walls of their two extremities; and it is interesting to observe, how very closely it thus corresponds with the contraction of certain Vegetable tissues, of which the component cells (§ 345) appear to produce a movement, when they are irritated, by means of a similar change of form. The essential difference, therefore, between the muscular tissue of Animals, and the contractile tissues of Plants, consists in the subjection of the former to nervous influence (§ 353). The diameter of the ultimate fibrillæ will of course be subject to variations, in accordance with their contracted or relaxed condition; but seems to be otherwise tolerably uniform in different animals, being for the most part about 1-10,000th of an inch. It has been observed, however, as high as 1-5000th of an inch, and as low as 1-20,000th, even when not put upon the stretch. The average distance of the striæ, too, is nearly uniform in different animals; though considerable variations present themselves in every individual, and in different parts of the same muscle. Thus the maximum distance varies in different animals from 1-15,000th to 1-20,000th of an inch; the minimum from 1-7500th to 1-4500th of an inch; while the mean does not depart widely in any instance from 1-10,000th.

Fig. 59.

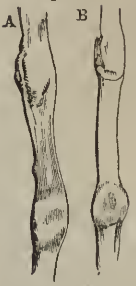


Structure of the ultimate fibrillæ of striated muscular fibre:—*a*, a fibril in a state of ordinary relaxation; *b*, a fibril in a state of partial contraction.

337. The Muscular fibre of Organic Life is very different from that which has been now described. It consists of a series of filaments, which do *not* present transverse markings; but which are tubular like the preceding, their contents having a granular consistence, without

any definite arrangement of the particles into disks or fibrillæ. Their size is usually much less than that of the striated muscular fibre; but owing to the extreme variation in the degree of flattening which they undergo, it is difficult to make even an average estimate of their dimensions. Those of the alimentary canal of Man are stated by Dr. Baly to measure from about the 1-2500th to the 1-5600th part of an inch in diameter. They generally present *nodosities* or enlargements at frequent intervals (Fig. 60); the character of which will be presently apparent. These fibres are, like those of the other muscles, arranged in a parallel manner into bands or fasciculi; but these fasciculi are generally interwoven into a network, without having any fixed points of attachment. It is of this kind of structure, that the proper muscular coat of the œsophagus, of the stomach and intestinal canal, and of the bladder, is composed; it makes up, also, the substance of the pregnant uterus; and it is found in no inconsiderable amount in the trachea and bronchial tubes. The fibres of the uterus somewhat differ in their aspect from those of other parts; being much broader at their centre, and tapering off towards their extremities. In the Heart, a mixture of the striated and non-striated fibres is found; a modification of the latter form of tissue exists in the middle coat of the arteries, especially in the smaller branches; and fibres of the same kind are interwoven with the other fibrous tissues in the substance of the skin, and especially in the dartos, giving it a contractility which is manifested under the influence of cold or of mental emotions, and thus producing that general roughness and rigidity of the surface, which are known as *cutis anserina*, and throwing the scrotum into wrinkles.

Fig. 60.



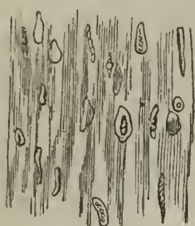
A. A muscular fibre of organic life from the urinary bladder, magnified 600 times, linear measure. Two of the nuclei are seen.

B. A muscular fibre of organic life, from the stomach, magnified 600 times. The diameter of this and of the preceding fibre, midway between the nuclei, was 1-4750th of an inch.

338. From the study of the early development of Muscular Fibre, it appears that the Myolemma, or external transparent tube, is the part first formed; this being distinctly visible, long before any traces of fibrillæ can be observed in it. This tube takes origin, like the straight ducts of Plants, in cells laid end to end; the cavities of which coalesce, by the disappearance of the partitions, at a subsequent period. The nuclei of these original cells may be distinctly seen, for some time after the appearance of the transverse striæ, which indicate the formation of the fibrillæ in their interior; and they project considerably from the sides of the fibres. In the fully-formed muscle of animal life, however, they are not perceptible, except when the fibre is treated with weak acid; the effect of which is to render the nuclei more opaque, whilst the surrounding structure becomes more transparent. They are usually numerous in proportion to the size of the fibre. There is every probability that these nuclei continue to act, like the "germinal spots" of the glandular follicles, as

centres of nutrition; from which the minute cells that compose the fibrillæ are developed as they are required. The diameter of the Muscular Fibre of the fœtus is not above one-third of that which it possesses in the adult; and as the *size* of the ultimate particles is the same in both cases, their *number* must be greatly multiplied during the growth of the structure. But we shall find reason to believe, that the decay of these particles is constantly taking place, with a rapidity proportional to the functional activity of the Muscle; and their generation, which occurs as continually, when the nutrient operations proceed in their regular course, is probably accomplished by a development from these centres, at the expense of the blood with which the Muscle is copiously supplied.

Fig 61.

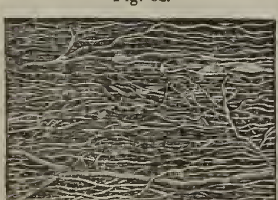


Mass of ultimate fibres from the pectoralis major of the human fœtus, at nine months. These fibres have been immersed in a solution of tartaric acid, and their "numerous corpuscles, turned in various directions, some presenting nucleoli," are shown.

339. From the preceding history it appears, that there is no difference, at an early stage of development, between the striated and the non-striated forms of muscular fibre. Both are simple tubes, containing a granular matter in which no definite arrangement can be traced, and presenting enlargements occasioned by the presence of the nuclei. But whilst the striated fibre goes on in its development, until the fibrillæ, with their alternation of light and dark spaces, are fully produced, the non-striated fibre retains throughout life its original embryonic condition.

340. We have seen that the Muscular tissue, properly so called, is as extra-vascular as cartilage or dentine; for its fibres are not penetrated by vessels; and the nutriment required for the growth of its contained matter is drawn by absorption through the myolemma. But the substance of Muscle is extremely vascular; the capillary vessels being distributed in nearly parallel lines, in the minute interspaces between the fibres; so that it is probable that there is no fibre, which is not in close relation with a capillary. Hence there is every provision for the active nutrition of this tissue; the arterial circulation bringing the materials for its growth and renovation; whilst the venous conveys away the products of the waste or disintegration, which is consequent upon its active exercise. The supply of blood is not merely requisite for the *nutrition* of the muscular tissue; but it also affords a condition which is requisite for its *action*. This condition is oxygen. It is not enough that blood should circulate through the muscles; for that blood, to exercise any beneficial influence, must be arterialized.

Fig. 62.



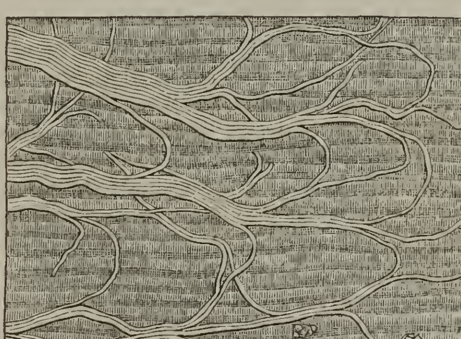
Capillary network of Muscle.

Consequently the muscles of warm-blooded animals soon lose their contractile power, after the supply of arterial blood has been suspended, either by the cessation of the circulation, or by the want of aëration of the blood; but those of cold-blooded animals preserve their properties for a much longer period, in accordance with the general principle formerly stated,—that, the lower the usual amount of vital energy, the longer is its persistence, after the withdrawal of the conditions on which it is dependent.

341. The Muscles of Animal Life are, of all the tissues except the Skin, the most copiously supplied with Nerves. These, like the blood-vessels, lie on the *outside* of the Myolemma of each fibre; and their influence must consequently be exerted through it. The arrangement of these nerves is shown in the succeeding figure. Their ultimate fibres or tubes cannot be said to terminate anywhere in the muscular substance; for after issuing from the trunks, they form a series of loops, which either return to the same trunk, or join an adjacent one. The occasional appearance of a termination to a nervous fibril is caused by its dipping-down between the muscular fibres, to pass towards another stratum.—The non-striated muscles, however, are very sparingly supplied with nerves; and these are derived,—for the most part, if not entirely,—from the Sympathetic system, rather than from the Cerebro-spinal.

342. Every Muscular Fibre, of the striated kind at least, is attached at its extremities to fibrous tissue; through the medium of which it exerts its contractile power on the bone or other substance, which it is destined to move. The muscular fibre usually ends abruptly by a perfect disk; and the myolemma seems to terminate there. The tendinous fibres are attached to the whole surface of the disk;

Fig. 63.



Portion of muscle, showing the arrangement of the motor nerves supplying it.

and probably become continuous with the myolemma. Thus the whole muscle is penetrated by minute fasciculi of tendinous fibres; and these collect at its extremities into a tendon. Sometimes the

muscular fibres are attached obliquely to the tendon, which forms a broad band that does not subdivide; this is seen in the legs of Insects and Crustacea, in which the muscular fibres have what is called a *penniform* arrangement, being inserted into the tendon, on either side, like the laminæ of a feather into its stem.—The *forms* which different muscles present, have reference purely to the mechanical purposes, which they have respectively to accomplish. The elements are the same in all, both as regards structure and properties.

343. Notwithstanding the energy of growth in Muscular tissue, it is doubtful if it is ever regenerated, when there has been actual loss of substance. Wounds of muscles are united by Areolar Tissue, which gradually becomes condensed; but its fibres never acquire any degree of contractility.

344. It is probable that the pure Muscular Fibre is identical in Chemical composition,—or nearly so,—with the Fibrin of the blood. It is, however, impossible to separate it completely from the areolar tissue, nerves, blood-vessels, fatty matter, &c., which enter into the substance of the muscle; so that it cannot be precisely analyzed. In ordinary muscle, the solid matter forms about 23 parts in 100; the remainder consisting of water.—The solid matter contains about $7\frac{1}{2}$ per cent. of fixed salts.

345. We now come to investigate the remarkable property, which is the distinguishing characteristic of Muscular tissue;—that of contracting on the application of a stimulus. Some approaches to this property are manifested by certain Vegetable structures. Thus, if the small enlargement at the base of the footstalk of the leaf of the Sensitive Plant, be touched ever so slightly, the leaf will be immediately drawn down by the contraction of the tissue of the part irritated. If the leaf itself be touched, the same effect results, but apparently through a different channel; the tissue of the leaf contracts where it is touched, and forces some of its fluid along the vessels of the footstalk into the upper side of the little excrescence at its base, by the distension of which the leaf is forced down. In the *Dionæa muscipula*, or Venus's Fly-trap, there is a similar transmission of the effect of the stimulus from one part to another; for the two lobes of the leaf, which form the trap, are made to close together, when an insect settles upon either one of three spines which project from the surface of each lobe, or when the points of these spines are touched with any hard body. Many other instances of Vegetable movement might be brought together. Some of them are obviously produced by an enlargement or contraction of the cells, occasioned by variations in the amount of fluid they contain; and these variations depend upon the hygrometric state of the atmosphere. With these we have nothing to do. But there are many, in which (as in the case of the Sensitive-plant first mentioned) a stimulus applied to a part occasions the immediate contraction of its cells, and a consequent motion in the *same* part. And there are also several, in which the contraction produces motion in a *distant* part, as in the Dionæa; but this propagation

appears to be of a simply mechanical character; being accomplished through the medium of fluid, which is forced from one part by its own contraction, and caused to distend another.

346. From these examples, however, it is evident that the property of contractility is not entirely restricted to the Animal kingdom; and we shall find that the simplest form under which it manifests itself in the Animal body, bears a close relationship with that which is displayed in Plants. The non-striated fibre of the alimentary canal, which is subservient to the functions of Vegetative life alone, is called into action much more readily by a stimulus directly applied to itself, than it is in any other mode. Such is not the case, however, with the striated fibre, of which the muscles of Animal life are composed; this being much more readily called into action by a peculiar stimulus conveyed through the nerves supplying those muscles, than in any other more directly applied to them.

347. The Contractility of Muscular Fibre shows itself under two forms. Its most obvious and striking manifestations are those that occur in the voluntary muscles and in the heart; which, when in action, exhibit powerful contractions alternating with relaxations. The property which is concerned in these is distinguished as *Irritability.* On the other hand, we find that these same muscles exhibit a tendency to a moderate and permanent contraction, which is not shown by them when they are dead, and which cannot, therefore, be the result of elasticity or of any simple physical property; this endowment, which seems to exist in the greatest amount in certain forms of the non-striated fibre, is called *Tonicity.*

348. That the irritability of Muscles is a property inherent in them, and in this respect analogous to the peculiar vital endowments of any other forms of tissue, cannot be any longer a matter of doubt;—though many Physiologists have sought to show, that it is in some way derived from the nerves. Not only may an entire Muscle be made to contract, by the application of a proper stimulus, long after the division of the nervous trunks supplying it; but even a single fibre, completely isolated from all its nervous connections, may be seen to contract under the Microscope. Moreover, in the non-striated muscular fibre, it is often difficult to excite contractions through the nerves at all, when a stimulus directly applied to itself will immediately produce sensible and vigorous movements. The energy of the contractile power depends in great part upon the state of nutrition of the muscle; and this again is influenced by the degree in which it is exercised. Now as the Muscles of Animal Life are all excited to action, in the usual state of things, through the medium of their nerves, it follows that if the nerves be paralyzed, the muscles will be seldom or never called into use. When disused, they will receive very little nourishment; the disintegrating changes will not be counterbalanced by reparative processes; and in consequence, the muscular structure will be gradually so far impaired, as to lose its peculiar properties,—and will even, in time, almost totally disappear. Yet even after the

almost complete departure of muscular contractility, through the metamorphosis of the structure consequent upon disuse, it may be again recovered, if the muscles be called into exercise; but the recovery of the power is very slow, and proceeds *pari passu* with the improvement in the nutrition of the part, being more tedious in proportion to the length of the previous disuse.

349. That the Irritability of Muscular fibre belongs to itself, and is not derived in any way from the nerves, is further shown in the following manner. If a set of muscles (as those of the leg of a Rabbit or Frog) be repeatedly thrown into action by galvanism, until the stimulus will no longer occasion their contraction, their irritability is then said to be exhausted; by rest, however, it is recovered,—the nutritive processes making good the loss previously suffered. Now it has been shown by Dr. J. Reid, that this recovery may take place, even after the division of all the nerves supplying the limb; provided that the nutrition of the part be not interfered with. It has been further shown by the same excellent Physiologist, that, if the nerves of a limb be divided, the loss or retention of the contractility of the muscles entirely depends upon the degree of exercise to which they are subjected, and consequently upon the nutrition they receive. The muscles of the hind-leg of a Rabbit, whose sciatic nerve had been divided, were found to lose their contractility almost completely in the course of seven weeks. They were much smaller, paler, and softer, than the corresponding muscles of the opposite leg; and they scarcely weighed more than half as much as the latter. Now when the nerves of *both* hind-legs of a Frog were cut, and the muscles of *one* of the limbs thus paralyzed were daily exercised by a weak galvanic battery, whilst those of the other were allowed to remain at rest, it was found after the lapse of two months that the muscles of the exercised limb retained their original size and firmness, and contracted vigorously, whilst those of the other had shrunk to one-half their former size. Though the latter still retained their contractility, there could be no doubt that they would soon lose it, in consequence of the change already far advanced in their physical structure; this change not being as rapid in cold-blooded animals, as in Birds and Mammals.

350. By these and other facts, then, it may be regarded as completely proved, that the Irritability of Muscles is a vital endowment, belonging to them in virtue of their peculiar structure;—that, so long as this structure is maintained in its normal condition by the nutritive processes, so long is the property capable of being manifested;—but that any cause which interferes with the nutrition of a muscle, impairs or destroys its irritability. No cause is so effectual in doing this, as complete *disuse;* and no means is so sure to produce complete disuse of a muscle, as the division of its nerve, since its being called into exercise in any other way is very improbable; hence the section of the nerve is almost certain to produce, in time, the loss of the contractility of the muscle. But if a means be devised, by which the

muscle may still be called into action in any other way,—as in Dr. Reid's experiment just quoted,—its irritability is retained, because its regular nutrition is continued.

351. We have now to inquire, then, into the circumstances under which this peculiar endowment acts; or the means by which it may be called into operation, the mode in which the contraction takes place, and the conditions which are necessary for its performance.—All Muscular Fibre, which has not lost its contractility, may be made to contract by a stimulus applied *directly* to itself; and this stimulus may be of different kinds. The simplest is the contact of a solid substance; thus we may excite muscular contractions by simply touching the fibre,—just as we cause contraction in the tissue of the Dionæa or Sensitive Plant. Most substances of strong chemical action, such as acids and alkalies, will call forth the contractility of muscular fibre, when applied to it; and the same result is produced by heat, cold, and electricity,—the last-named agent being the most powerful of all. The effect of the application of any of these stimuli varies considerably, according to the kind of Muscle on which it is exerted. If we irritate a portion of a muscle composed of striated fibre (any one of the voluntary muscles for example), the fasciculus of fibres which is touched will immediately contract, and that one only; and the contracted fasciculus will soon relax, without communicating its movement to any other.

352. If we irritate a portion of non-striated fibre, however, as that of the Alimentary canal, the fasciculus which is stimulated will contract less suddenly, but ultimately to a greater amount; its relaxation will be less speedy; and before it takes place, other fasciculi in the neighbourhood begin to contract; their contraction propagates itself to others; and so on. In this manner, successive contractions and relaxations may be produced through a considerable part of the canal, by a single prick with a scalpel; a sort of wave of contraction being transmitted in the direction of its length, and being followed by relaxation. Again, in the Muscular structure of the Bladder and Uterus, powerful contractions are excited by irritation, and these produce a great degree of shortening; but they do not alternate in the healthy state with any rapid and decided elongation; whilst, on the other hand, an irritation applied to one spot causes more extensive contractions than are seen to occur as its immediate consequence in the preceding cases. In the Heart, the muscular structure of a large part of the organ is thrown into rapid and energetic contraction, by a stimulus applied at any one point; and this contraction is speedily followed by relaxation. And in the fibrous tissue of the middle coat of the Arteries, the contraction takes place rather after the manner of that of the bladder and uterus, and a prolonged application of the stimulus is often necessary to produce the effect; but when the contraction commences, it produces a considerable degree of shortening, which takes place in other fasciculi than those directly irritated, and does not speedily give way to relaxation.

353. On the other hand, when the stimuli which excite muscular contraction are applied to the nerve, which supplies a voluntary muscle composed of striated fibre, they produce a simultaneous contraction in the whole muscle; the effect of the stimulus being at once exerted upon every part of it. In the ordinary action of such muscles, the nervous system is always the channel through which they are called into play, whether to carry into effect the determinations of the mind (§ 391), or to perform some office necessary to the continuance of life, such as the movements concerned in Respiration (§ 394). The nerves of the striated fibre are all derived at once from the brain or spinal cord.—The ordinary actions of the non-striated fibre, on the contrary, are executed in respondence to stimuli applied directly to themselves. It is so difficult to excite contractions in it through the medium of its nerves, that many Physiologists have denied the possibility of doing so; and the nerves lose their power of conveying the influence of stimuli very soon after death, although the contractility of the muscles may remain for a considerable time. The nerves of the non-striated fibre are chiefly those belonging to the Sympathetic system; but, as will be shown hereafter (Chap. XII.), those which excite motion are probably derived in reality from the Cerebro-spinal system, through the communicating branches which unite the two.

354. When a Muscle is thrown into contraction, its bulk does not appear to be at all affected. Its extremities approach, so that it is shortened in the direction of its fibres; but its diameter enlarges in the same proportion. It was formerly supposed that the ultimate fibres, in the act of contraction, threw themselves into zigzag folds; but this is now well ascertained not to be the case. The fibre, like the entire muscle, preserves its straight direction in shortening, and increases in diameter. The fibrillæ themselves, as already mentioned (§ 336) exhibit an evident change, in regard to the distances of their successive light and dark portions; and the fibre, which is made up of these, exhibits, in its contracted state, a very close approximation of the transverse striæ; to such an extent that they become two, three, or even four times as numerous in a given length, as they are in a similar length of a non-contracted fibre. According to Mr. Bowman's observations, the contraction usually commences at the extremities of a fibre; but it may occur also at one or more intermediate points. The first appearance of contraction is a dark spot, caused by the approximation of the striæ; and this gradually extends itself, so as to involve a greater or less proportion of the length of the fibre. The approximation of the solid portions forces out the fluid, which was previously contained amongst the fibrillæ; and this is seen to lie in bullæ or blebs beneath the myolemma, which is drawn up into wrinkles.

355. The successive stages of the act of contraction can only be thus observed, when it takes place very slowly, as in the *rigor mortis*, or slow contraction after death, the phenomena of which will be presently noticed. But the resulting change in muscular fibres, which

have been made to contract by galvanism or any other stimulus, is essentially the same. This may be best seen in transparent Entozoa, Crustacea, and others among the lower Articulated Animals, whilst alive. Again, in persons who have died from Tetanus, a considerable number of the fibres are found to have been ruptured by the violent spasmodic action ; the contractile force, called into action by the powerful stimulation of the nerves, having overcome the tenacity of the fibre: and in such cases, the same approximation of the transverse striæ, and proportional increase in the diameter of the fibre, are to be observed.

356. It appears that, even when considerable force of contraction is being exerted, the *whole* fibre is seldom or never in contraction at once; but that a continual interchange is taking place amongst its different parts,—some of them passing from the contracted to the relaxed state, as shown by the separation of the transverse striæ,—whilst others are taking up the duty, and passing from the relaxed to the contracted condition, as shown by the approximation of the striæ. But it is not only among the different parts of the individual fibres, that this interchange seems to take place. There is good reason to believe that, when a muscle is kept in a contracted state, by an effort of the will, for any length of time, only a part of its fibres are in contraction at any one time; but that a constant interchange of condition takes place amongst them, some contracting whilst others are relaxing, so that the entire muscle remains contracted, whilst the state of every individual fibre may have undergone a succession of alterations. When the ear is applied to a muscle in vigorous action, an exceedingly rapid faint silvery vibration is heard, which seems to be attributable to this constant movement in its substance.

357. Thus it appears that the prolongation of the contraction of a muscle, through any length of time, is not opposed to the fact that, in the individual fibres, relaxation speedily follows contraction; but is only a peculiar manifestation of it. The ordinary movements of the Heart exhibit a different manifestation ; its fibres contracting simultaneously, and relaxing together, instead of alternating amongst themselves like those of a voluntary muscle.—The occasional zigzag arrangement of the fibres, which has been supposed to be their contracted state, is really dependent upon the approximation of their extremities, in consequence of the contraction of some neighbouring fibres, whilst their own condition is that of relaxation. It may be artificially produced by bringing together the two extremities of a fasciculus, after the irritability of the fibre has ceased; so that the flexure at determinate points must be owing simply to the physical arrangement of the parts,—perhaps to the passage of nerves or vessels in a transverse direction.

358. We have now to consider the conditions, which are requisite for the manifestation of Muscular Irritability. It has been already pointed out, how close is the dependence of the property upon the due *nutrition* of the tissue; but the property cannot be long exercised ex-

cept under another condition, which is consequently of almost equal importance,—the circulation of arterial blood through the substance of the muscle. The length of time during which the contractility remains, after the circulation has ceased, has been shown by Dr. M. Hall to vary inversely to the activity of the respiration of the animal. Thus in cold-blooded animals, the standard of whose respiration is low, the contractility remains for many hours after death, even in the voluntary muscles; and the muscles of organic life retain it with great tenacity. Thus the heart of a Frog will go on pulsating for many hours after its removal from the body; and the heart of a Sturgeon, which had been inflated with air and hung up to dry, has been seen to continue beating, until the auricle had become absolutely so dry, as to rustle during its movements. An exceedingly feeble Galvanic current is sufficient to excite the muscles of these animals to contraction; so that Matteuci, in his experiments upon Animal Electricity, has been accustomed to use the prepared hind-leg of a Frog as the best indicator of the passage of an electric current. Among warm-blooded animals, the same rule holds good, in regard to the inverse proportion of the duration of irritability, and the amount of respiration; for the muscles of Birds lose this property at an earlier period after the cessation of the circulation, than do those of Mammals. From experiments on the bodies of executed criminals, who were previously in good health, Nysten ascertained that, in the human subject, the contractility of the several muscular structures, as tested by Galvanism, departs in the following time and order:—the left ventricle of the heart first; the intestinal canal at the end of 45 or 55 minutes; the urinary bladder nearly at the same time; the right ventricle after the lapse of an hour; the œsophagus at the expiration of an hour and a half; the iris a quarter of an hour later; and lastly, the ventricles of the heart, especially the right, which in one instance contracted $16\frac{1}{2}$ hours after death.

359. That the circulation of arterial or oxygenated blood through the muscles, is the essential condition of the continuance of their irritability, appears from this,—that after the general death of the system, and even after the removal of the brain and spinal cord, the muscles will preserve their irritability, and the action of the heart itself will continue for a long time, provided that the circulation be kept up through the lungs by artificial respiration, on the principles hereafter to be explained. (§ 688.) But if, whilst the general circulation continues, the circulation through a particular muscular part be interrupted, that organ will lose its contractility earlier than usual. Thus it has been shown by Mr. Erichsen, that, if the coronary arteries (supplying the substance of the heart) be tied in a dog or a rabbit, after the animal has been pithed, and the circulation is being maintained by artificial respiration, the pulsation of the heart will only go on for about 23 minutes after the ligature has been applied, or about 33 minutes after the death of the animal; instead of continuing for 90 minutes, which it will do under other circumstances. Further, if blood

charged with carbonic acid, instead of with oxygen, circulate through the muscles, their irritability is speedily impaired, and is even destroyed. This is best seen, when animals are killed by being caused to breathe an atmosphere highly charged with carbonic acid; the irritability of their muscles departing as soon as they are dead. In fact, the destruction of the irritability of the heart, by the circulation of venous blood through its substance, is one of the immediate causes of death. A similar effect is produced by the respiration of other gases, which are either poisonous in themselves, or which prevent the interchange of carbonic acid and oxygen, which ought to take place in the lungs. On the other hand, when animals have been made to respire oxygen, and their blood has been consequently highly arterialized, the contractility of their muscles is retained for a longer time than usual.

360. Hence we may conclude the presence of oxygen in the blood to be one of the conditions of muscular contraction; although it is much less essential in the case of cold-blooded, than in that of warm-blooded animals. It is interesting to remark, that the muscles of *hybernating* warm-blooded Mammals are reduced for a time to the level of those of cold-blooded animals; their contractility being retained almost as long as that of the latter; thus confirming the general principle already stated as to the relation between the amount of respiration, and the duration of the irritability.

361. The Muscles, as we have seen, are largely supplied with blood; and the flow of blood into them increases with the use that is made of them. The demand for nutrition is obviously augmented, in proportion to the activity of the exercise of the Muscular system; for the slightest observation suffices to show, that a much smaller amount of nourishment is sufficient to sustain the body in its normal condition, when the Muscular system is not actively exercised, than when it is in energetic operation. The quantity which is ample for an individual leading an inactive life, is far too little for the same person in the full exercise of his muscular powers. Again, there is evidence derived from observation of the relative amount of the solid matters excreted from the body under different circumstances, that a *waste* or *disintegration* of the muscular tissue takes place, whenever it is actively employed; and this in a degree strictly proportional to the amount of force which it is called upon to exercise. In fact, it would appear that this waste is a necessary consequence of the exercise of the muscle;—every act of contraction involving the death and decomposition of a certain amount of tissue. And as the presence of oxygen is always necessary for the decomposition of organic substances, so do we find that the penetration of the muscular tissue by oxygenated blood is essential to the manifestation of its contractile power.

362. Every act of contraction, then, may be said to involve the death of a certain amount of muscular tissue; and the products of decomposition which consist of the elements of muscular fibre united with the oxygen of the arterial blood, are carried off by the

venous current. On the other hand, the muscular substance is repaired by an act of nutrition, at the expense of the fibrin supplied to it by the circulating fluid. There are certain muscles, as the heart, and the muscles of respiration, whose action is necessarily constant; and their reparation must take place as unceasingly as their waste. In these muscles no sense of fatigue is ever experienced. But in the muscles which are usually put in action by the will, this is not the case. Any prolonged exertion of them induces fatigue; and this fatigue is an evidence of their impaired condition, and of the necessity of rest to impart to them a renewal of vigour. The *rest* of muscles is essential to the recovery of their powers; and this recovery is due to the nutritive operations, which then take place unchecked, and which repair the losses previously sustained. The permanently increased flow of blood to a muscle, which takes place when it is continually being called into vigorous action, is thus on the one hand occasioned by the demand for oxygenated blood created by its use, whilst on the other hand it tends to increase the power of the muscle by an augmentation of its nutrition. Hence it is, that the more a muscle is exercised, the more vigorous and more bulky does it become. This is equally the case whether the exercise of the muscle be voluntary or not. We see examples of it in the arms of the smith and in the legs of the opera dancer; and we have a still more striking manifestation of it in those cases, in which an obstruction to the exit of urine through the urethra, has called for increased efforts on the part of the bladder, the continuance of which gives rise to an extraordinary augmentation in the thickness of its muscular coat.

363. Thus we see that the property of Irritability is a vital endowment peculiar to muscular tissue, and dependent for its existence upon due nutrition of that tissue; that it may be called into exercise by certain stimuli, applied either to the muscle itself, or to the nerve supplying it, provided that the muscle be also permeated with oxygen; that it may be exhausted by repeated stimulation, but is then recovered by rest, provided that there be no obstacle to the nutrition of the muscle; that the nutrition of the muscle is impaired by continued repose, and that its irritability diminishes in the same proportion; that the nutrition is increased by frequent use, and that the power of the muscle then augments in like degree; and finally that the departure of muscular power, which ensues upon the general death of the system, is dependent in part upon the cessation of the supply of oxygen, and in part upon changes in the composition of the muscle itself, which are no longer compensated by the functions that keep it in its normal condition during life.—The rapidity of these changes is the greatest in warm-blooded animals, in which also the muscular irritability is most dependent upon the presence of oxygen in the muscular substance; consequently the irritability departs after death much more speedily in these than in cold-blooded animals.

364. We have now to consider the other form of Contractility, which produces a *constant* tendency to contraction in the Muscular

fibre, but which is so far different from simple Elasticity, that it abates after death, before decomposition has taken place. This Tonicity manifests itself in the retraction which takes place in the ends of a living muscle, when it is divided; the retraction being permanent, and greater than that of a dead muscle. It also shows itself in the permanent flexure of joints, when, by paralysis of the extensors, the tonic contraction of the flexors is not antagonized. In the healthy state, it would seem as if the tonicity of the several groups of muscles was so adjusted, as to be in mutual counterpoise; but the balance is destroyed when, in consequence of paralysis, or of impaired nutrition from other causes, the tonicity of one set is weakened. This is the case, for example, in the lead-palsy; in which the extensors of the forearm and hand lose their power, so that the tonic contraction of the flexors keeps the fingers constantly bent upon the palm. It would seem, however, that the tonicity of the flexors is usually greater than that of the extensors; as the former predominate, when all are equally withdrawn from the control of the nervous system, in profound sleep.

365. The Tonicity is much greater, relatively to the amount of irritability, in the non-striated, than in the striated fibre; and it is particularly remarkable in the fibrous coat of the arteries, in which it is difficult to procure any decided indication of irritability by the application of stimuli. It is by this tonicity of the walls of the arteries, that they are kept in a state of constant moderate contraction upon their contents; and that, when they are emptied, they contract until the tube is nearly obliterated. If its amount be too great (as sometimes happens) the artery approaches the condition of a rigid tube; which, as will be shown hereafter, is unfavourable to the regularity of the flow of blood through it, though the rate is increased. On the other hand, if it be unduly diminished, the circulation is retarded, by the tendency of the arterial walls to yield too much to the pulse-wave.

366. This property is very greatly affected by temperature; being diminished by warmth, and increased by cold. Thus when an artery is exposed to the air for some time, the lowering of its temperature occasions its contraction to such an extent, that its tube may be almost obliterated. And in the operation of *crimping* fish, immersion of the body in cold water, after the muscles have been divided, increases the tonic contraction of the muscles, and thus improves the firmness to their substance, which it is the object of this operation to produce.

367. The *Rigor Mortis*, or death-stiffening of the muscles, is probably to be regarded as a manifestation of this property, occurring after all the Irritability of the muscles has departed, but before any putrefactive change has commenced. This phenomenon is rarely absent; although it may be so slight, and may last for so short a time, as to escape observation. The period which elapses before its commencement is as variable as its duration; and both seem to be dependent upon the vital condition of the system at the time of death.

When it has been weakened or depressed by previous disease, the irritability of the muscles speedily departs; and the stiffening comes on early, and lasts but a short time. Thus, after death from Typhus, the limbs have been sometimes known to stiffen within 15 or 20 minutes. On the other hand, when the general vigour of the system has not been previously impaired, and death has resulted from some sudden cause, the irritability of the muscles is of longer duration, and their stiffening is consequently deferred. The commencement of the rigidity usually takes place within seven hours after death; but twenty or even thirty hours may elapse before it shows itself. Its general duration is from twenty-four to thirty-six hours; but it may pass off much more rapidly, or it may be prolonged through several days. It affects all the muscles composed of the striated fibre with nearly the same intensity; except that the flexors usually contract more strongly than the extensors (as in sleep), the fingers being closed upon the palm, the hand bending on the forearm, and the lower jaw being drawn firmly against the upper. And it even manifests itself in muscles that have been thrown out of use by paralysis, provided that their nutrition has not been seriously impaired.

368. This tonic contraction, however, is most remarkably manifested in the non-striated fibre; and especially in the heart and blood-vessels. As soon as the muscular walls of the several cavities lose their irritability, they begin to contract forcibly upon their contents, and thus become stiff and firm, although they were previously flaccid. In this manner, the ventricles of the heart, which are the first parts to lose their irritability, become rigid and contracted within an hour or two after death; and usually remain in that state for ten or twelve hours, sometimes for twenty-four or thirty-six, then again becoming relaxed and flaccid. This rigid contracted state of the heart, in which the walls are thickened and the cavities diminished, was formerly supposed to be a result of disease, and was termed concentric hypertrophy; but it is now known to be the natural condition of the organ, at the period when the rigor mortis occurs in it.—The contraction of the arterial tubes is so great, as to produce for the time a great diminution in their calibre; and this, doubtless, contributes to the passage of the blood from the arterial into the venous system, which almost invariably takes place within a few hours after death. The arteries then enlarge again, and become quite flaccid, their tubes being emptied of the previous contents; and it was from this circumstance, that the ancient physiologists were led to imagine that the arteries are not destined to carry blood, but air.

369. As soon as the Rigor Mortis departs, the muscles pass into a state of decomposition; in fact, it is by the commencement of decomposition, that the cessation of this vital property is occasioned. Thus we may regard the Rigor Mortis as the last act of the Muscular Contractility; and in this respect it corresponds with the coagulation of the blood, which also is the closing act of its life, when it is drawn from the living body, or has ceased to circulate (§ 184).

There are, indeed, many remarkable points of correspondence between the two phenomena; which have induced some physiologists to believe, that *rigor mortis* is in fact nothing else than the coagulation of the blood in the muscles. It has been shown by Mr. Bowman, however, that the stiffening of the muscles after death is due to the permanent contraction of their component fibres, and that the coagulation of the blood can have nothing to do with it. Nevertheless, this contraction may be considered as being, for the muscular fibre, very much the same kind of phenomenon as the coagulation of the fluid fibrin of the blood,—especially resembling the subsequent contraction of the clot, which takes place gradually, within a few hours after its separation. The causes which prevent the coagulation of the blood after death (§ 187), usually prevent also this last manifestation of the tenacity of the muscles; their vitality being completely destroyed, like that of the blood, by sudden and powerful shocks operating on the nervous system, or by the complete exhaustion consequent upon violent and long-continued exertion, as when animals are run to death. And again, the tonicity of muscles survives the freezing process; manifesting itself by contraction and rigidity, in a muscle that has been frozen immediately after death, and is subsequently thawed; just as the peculiar properties of the fibrin of the blood cause its coagulation upon being thawed, if it have been frozen immediately upon being drawn from the vessels.

370. The power by which the elements of Muscular fibre are caused to approach one another in the exercise of their Contractility, differs from any other with which we are acquainted. Its complete dependence upon the life of the tissue is remarkably shown by the fact (ascertained by Valentin), that, after the cessation of the irritability, the muscles *tear* with a far less weight, than they were previously able to *draw*, when excited by galvanism; so that their contractile force is much greater than that, which the simple cohesiveness of the tissue can sustain. Moreover, it has been shown by the experiments of Schwann, that the contractile force is greatest, when the muscle is most extended; so that, with the same stimulus, it can overcome a greater resistance by its contraction, when it has been previously stretched to its full length, than it can when it has been already in part shortened by the exercise of its contractile force. The power diminishes progressively with the further shortening of the muscle; until at last no further contraction can be produced by any stimulus, the extreme limit having been reached. Hence it seems as if the contractile force of Muscles differs completely from other forms of Attraction, as those of Gravitation, Electricity, &c.; since it is the universal law of *their* operation, that the force *increases*, in proportion to the decrease between the squares of the distances between the attracting bodies; whilst, in the case of muscle the force *decreases*, in proportion as the distance between the attracting particles decreases. But it is to be remembered that the law of attraction just quoted supposes the particles to be quite free to approach one another; and this

they obviously are not in the contraction of a Muscle, since the approach cannot take place without a change of place between the solid and fluid elements (§ 354). Hence it is difficult, if not impossible, to discover the law, which shall truly express the nature of the attraction between the ultimate particles of Muscle at different distances; but the law discovered by Schwann expresses the force actually developed, at the different states of muscular contraction.

371. It has been ascertained by the researches of MM. Becquerel and Breschet, that the temperature of a muscle rises, when it is thrown into energetic contraction. The increase is ordinarily but about 1° Fahr.; but it may amount to twice as much, if the muscle be kept in action for some time, as in the exercise of sawing. Two causes may be assigned for this increase. It may depend upon the chemical changes which take place in the Muscles, as a necessary condition of the production of its force (§ 361); or it may be the result of the friction taking place between different parts, during the constant interchange of their actions (§ 356). Perhaps both these causes concur in producing the effect.

372. The *Nervous System*, taken as a whole, is the instrument of all those operations, which peculiarly distinguish the Animal from the Plant; and it serves many additional purposes, connected with the Organic or Vegetative functions, which the peculiar arrangements of the Animal body involve. Wherever a distinct Nervous System can be made out (which has not yet been found possible in the lowest Animals), it consists of two very different forms of structure; the presence of both of which, therefore, is essential to our idea of it as a whole. We observe, in the first place, that it is formed of *trunks*, which are distributed to the different parts of the body, especially to the muscles and to the sensory surfaces; and of *ganglia*, which sometimes appear merely as knots or enlargements on these trunks, but which, in other cases, have rather the character of central masses, from which the trunks proceed. Now it is easily established by experiment, that the *active powers* of the nervous system reside in the *ganglia;* and that the *trunks* serve merely as *conductors* of the influence which is to be propagated towards or from them. For if a trunk be divided in any part of its course, all the parts to which the portion thus cut off from the ganglion is distributed, are completely paralyzed; that is, no impression made upon them is felt as a sensation, and no motion can be excited in them by any act of the mind. Or if the substance of the ganglion be destroyed, all the parts, which are exclusively supplied by nervous trunks proceeding from it, are in like manner paralyzed. But if, when a trunk is divided, the portion still connected with the ganglion be pinched, or otherwise irritated, sensations are felt, which are referred to the points supplied by the separated portion of the trunk; which shows that the part remaining in connection with the ganglion is still capable of conveying impressions, and that the ganglion itself receives these impressions and makes them felt as sensations. On the other hand, if the separated portion

of the trunk be irritated, motions are excited in the muscles which it supplies; showing that it is still capable of conveying the motor influence, though cut off from the usual source of that influence.

373. When we minutely examine the trunks of the nerves, we find that they are composed, in the first place, of a *Neurilemma* or nerve-sheath, consisting of white fibrous tissue; the office of which is evidently that of protecting the nerve-tubes, and of isolating them from the surrounding structures, at the same time that it allows blood-vessels to pass into the interior of the trunk. From the interior of the neurilemma, thin layers of areolar tissue pass into the midst of the enclosed bundle of nervous fibrẽs; separating it into numerous smaller fasciculi, which are thus bound together, and supplied with blood-vessels. The capillaries are distributed very much on the same plan as those of Muscular tissue (Fig. 62); the network being composed of straight vessels, which run along the course of the nerve, between the nerve-tubes, and which are connected at intervals by transverse vessels.—When the neurilemma has been removed, and the trunk has been separated into its component fasciculi, we may still further subdivide the fasciculi themselves, by careful dissection, until we arrive at the ultimate nervous fibre, which is the essential element of the structure. Two forms of this fibre exist in the nerves of higher animals, bearing a considerable analogy to the two forms of the Muscular fibre; one appearing to be the special instrument of the *animal* functions; and the other, which seems to be less perfectly formed, having a connection (the nature of which is not yet well understood) with the *organic*. These require a separate description.

374. The Nervous fibre, in its most complete form, is distinctly tubular. It is composed externally of a very delicate transparent membrane, which is apparently quite homogeneous; this is obviously analogous to the myolemma of the Muscular fibre, and serves, like it, to isolate the contained substance most completely from surrounding structures. This membranous tube is not penetrated by blood-vessels, nor does it branch or anastomose with others; and there is reason to believe it to be continuous from the origin to the termination of the nervous trunk. Within the tube is a hollow cylinder of a material, known as the *White substance of Schwann*, which differs in composition and refracting power from the matter that occupies the centre of the tube, and of which the outer and inner boundaries are marked out by two distinct lines. And the centre or axis of the tube is occupied by a transparent substance, which is termed the *axis-cylinder*. There is reason to believe that this last is the essential component of the nervous fibre; and that the hollow cylinder which surrounds it, serves, like the external investment, chiefly for its complete isolation. The whole of the matter contained in the tubular sheath is extremely soft; yielding to very slight pressure. The tubular sheath itself varies in density in different parts; being stronger in the nervous trunks, than in the substance of the brain and spinal cord. In the former, it is not difficult to show, that the regular form of the nerve-tube is a

perfect cylinder; though a little disturbance will cause an alteration in this,—a small excess of pressure in one part forcing the contents of the tube towards another, where they are more free to distend it, and thus producing a swelling. The greater delicacy of the tubular sheath in the latter causes this result to take place with yet more readiness; so that a very little manipulation, exercised upon the fibres of the brain and spinal cord, or on those of special sense, occasions them to assume a *varicose* or beaded appearance, which, when first observed by Ehrenberg, was thought to be characteristic of them. When the fibres of these parts, however, are examined without any such preparation, they are found to be as cylindrical as the others.—The diameter of the tubuli is usually between 1-2000th and 1-4000th of an inch. Sometimes, however, it is as much as 1-1500th; and occasionally as little as 1-14000th. They are larger in the nerve-trunks than in the brain; and they diminish in the latter as they approach the cortical substance. The fibres of the nerves of special sense are smaller than the average, in every part of their course.

375. The *organic* nervous fibres (termed *gelatinous* by Henle) are chiefly found in the Sympathetic system, and may be regarded as its distinctive element; but, as we shall see hereafter (Chap. XII.), they are mixed up with the preceding in the ordinary nervous trunks. These fibres cannot be shown to consist of the same variety of parts as the preceding; no tubular envelop can be distinguished; and the white substance of Schwann seems wanting. They are flattened, soft, and homogeneous in their appearance, bearing a considerable resemblance to the unstriped Muscular fibres; and, like them, they contain numerous cell-nuclei, which are arranged with tolerable regularity. These nuclei are brought into view by acetic acid, which dissolves the rest of the fibre, leaving them unchanged. The organic fibres are usually of smaller size than the tubular, their diameter averaging between the 1-6000th and the 1-4000th of an inch; and they sometimes show a disposition to split into very delicate fibrillæ. Being of a yellowish-gray colour, they have been sometimes distinguished as the *gray* fibres.

376. Both classes of fibres appear to run continuously, from one extremity of the nervous cord to the other, without anything like union or anastomosis; each ultimate fibre probably having its distinct office, which it cannot share with another. The fasciculi, or bundles of fibres, however, occasionally intermix and exchange fibres with each other; and this interchange may take place among either the fasciculi of the same trunk, or among those of different trunks. Its object is evidently to diffuse among the different branches the endowments of a particular set of fibres. Thus we shall hereafter see that, in all the Spinal Nerves of Vertebrata, one set of roots ministers to sensation, and another to motion; the sensory fibres are *principally* distributed to the skin, and the motor fibres to the muscles; but every branch contains both sensory and motor fibres, which are brought together by the interlacement of those connected with both sets of

roots. In the head, we have some nervous trunks which have sensory roots alone; and others which have motor roots only; these in like manner acquire each other's functions in some degree by an interchange of filaments,—the sensory trunk receiving motor fibres, and the motor trunk receiving sensory fibres. An interchange of this kind, upon a very extensive scale, takes place between the Cerebro-spinal system, whose ganglionic centres are the brain and spinal cord, and the sympathetic system, whose centres consist of a number of scattered ganglia. The former sends a large number of *tubular* fibres into the latter, by the twigs of communication near the origins of the Spinal nerves, as well as by their connecting branches; whilst the latter sends a smaller number of *gray* or *organic* fibres into the former.

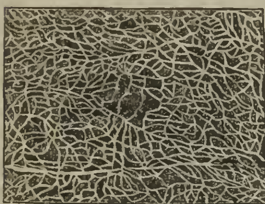
377. Sometimes we find the fasciculi of several distinct trunks united into an extensive plexus; the sole object of which appears to be, to give a more advantageous distribution to fibres, which all possess corresponding endowments. Thus the *brachial* plexus mixes together the fibres arising by five pairs of roots, on either side, from the spinal cord; and sends off five principal trunks to supply the arm. Now if each of these trunks had arisen by itself, from a distinct segment of the spinal cord, so that the parts on which it is distributed had only a single connection with the nervous centres, they would have been much more liable to paralysis than they are. By means of the plexus, every part is supplied with fibres arising from each of the five segments of the spinal cord; and the functions of the whole must, therefore, be suspended, before complete paralysis of any part could occur, from a cause which operates above the plexus. This may be experimentally shown on the Frog, whose crural plexus is formed by the interlacement of the component fasciculi of three trunks on each side; for section of the roots of one of these produces little effect on the general movements of the limb; and even when two are divided, there is no paralysis of any of its actions, all being weakened in nearly an equal degree. It is possible that by the plexiform arrangement, a *consentaneousness* of action is in some degree favoured, where several distinct *motions* are to be combined in one *movement;* something of the same kind is to be met with in numerous instances, among the lower animals, in which the same purpose has to be attained.

378. The second primary element of the Nervous System, without which the fibrous portion would seem to be totally inoperative, is composed of nucleated cells, containing a finely granular substance, and lying somewhat loosely in the midst of a minute plexus of blood-vessels. Their normal form may be regarded as globular (hence they have been termed *nerve* or *ganglion-globules*); but this is liable to alteration from the compression they suffer, so that they may become oval or polygonal. The most remarkable change of form, however, which they undergo, is by an extension into one or more long processes, giving them a *caudate* or a *stellate* aspect. These

15

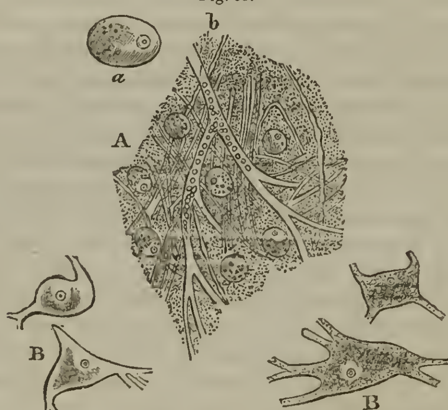
processes, according to Messrs. Todd and Bowman, are composed of a finely-granular substance, resembling that of the interior of the vesicle, with which they seem to be distinctly continuous. They are very liable to break off near the vesicle; but if traced to a distance, they are found to divide and subdivide, and at last to give off some extremely fine transparent fibres, which seem to interlace with those of other stellate cells, and which may perhaps (though this is at present only a surmise) become continuous with the axis-cylinders of the nerve-tubes. The size of the vesicles is liable to great variation; the globular ones are usually between 1-300th and 1-1250th of an inch in diameter.—Besides the finely-granular substance just mentioned, these cells usually contain

Fig. 64.



Capillary Network of Nervous Centres.

Fig. 65.



Primitive fibres and ganglionic globules of human brain, after Purkinje. A, ganglionic globules lying amongst varicose nerve-tubes, and blood-vessels, in substance of optic thalamus; *a*. globule more enlarged; *b*, small vascular trunk. B, B, globules with variously-formed peduncles, from dark portion of crus cerebri. 350 Diam.

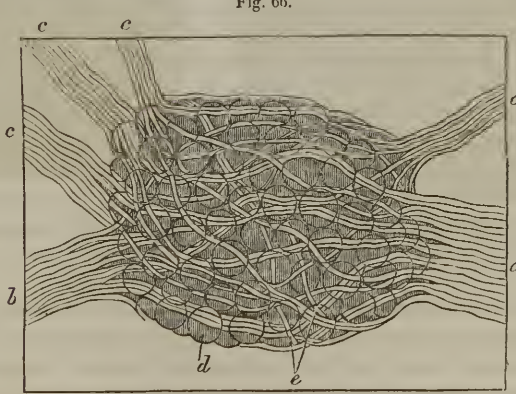
a collection of pigment-granules, which give them a reddish or yellowish-brown colour. This, however, is frequently absent, especially among the lower animals.

379. The vesicles just described are aggregated together in masses of variable size; and are in some degree held together by the plexus of blood-vessels, in the midst of which they lie. They are sometimes imbedded in a soft granular substance, which adheres closely to their exterior and to their processes; this is the case in the outer part of the cortical substance of the human brain. In other instances, each cell is enclosed in a distinct envelop, composed of smaller cells, closely adherent to each other and to the contained cell; such an

arrangement is common in the smaller ganglia, and in the inner portion of the cortical substance of the brain.—The substance, which is made up of these peculiar cells, of the plexus of the blood-vessels in which they lie, and of the granular matter that is disposed amongst them, is altogether commonly known as the *cineritious* or *gray* substance; being distinguished by its colour, in Man and the higher animals at least, from the *white* substance (composed of nerve-tubes) of which the trunks of the nerves, as well as a large part of the brain and spinal cord, are made up. But this distinction is by no means constant; for the gray colour, which is partly due to the pigment-granules of the cells, and partly to the redness of the blood in the vessels, is wanting in the Invertebrata generally, and is not characteristically seen in the classes of Fishes and Reptiles. Moreover, when the ganglionic substance exists in small amount, even in Man, its colour is not sufficiently intense to serve to distinguish it; and, as we have already seen, there are nerve fibres which possess a grayish hue. The real distinction evidently lies in the *form* of the ultimate structure, which is *fibrous* in the one case, and *cellular* or *vesicular* in the other; and these terms will be henceforth used to characterize the two kinds of Nervous tissue, which have been now described.

380. A *ganglion*, then, essentially consists of a collection of nerve-vesicles or ganglion-globules, interspersed among the nerve-fibres; and it is in the presence of the former, that it differs from a *plexus*, which it frequently resembles in the arrangement of the latter. When a nerve enters a ganglion, its component fibres separate and pass through the ganglion in different directions, so as to be variously distributed among the branches which pass out of it. In their

Fig. 66.



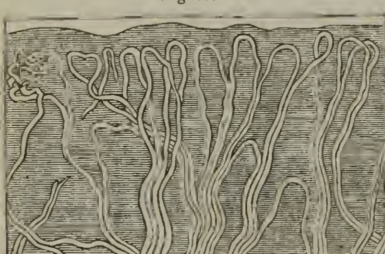
Dorsal ganglion of Sympathetic nerve of Mouse;—*a*, *b*, cords of connection with adjacent sympathetic ganglia; *c*, *c*, *c*, *c*, branches to the viscera and spinal nerve; *d*, ganglionic globules or cells; *e*, nervous fibres crossing the ganglion.

course, they come in contact with the vesicular matter, which occupies the interior of the ganglion: and it appears from Mr. Newport's

observations, that they then become softer, and that their diameter increases.—The only exception to the general fact, that the vesicular matter occupies the centre of the ganglia, occurs in the brain of Vertebrata, in which it is chiefly disposed on the exterior, forming the *cortical* envelop. The reason for this variation is probably to be found in the very large amount of this substance, which the brain of the higher Vertebrata contains; and in the necessity of the free access of blood-vessels to it, which is provided for by a great extension of its surface beneath the investing vascular membrane (pia mater), more readily than it could be in any other mode.

381. But the vesicular matter is not found in the *central* masses only of the Nervous System; for it presents itself also at those parts of the *surface* or *periphery*, which are peculiarly destined to receive the impressions that are to be conveyed to the central organs. Thus on the expansion of the optic nerve which forms the retina, there is a distinct layer of ganglionic corpuscles or nerve-cells, with a minute plexus of vessels; possessing all the essential characters of the vesicular substance of the brain. Something of the same kind has been seen in connection with the corresponding expansions of the olfactive and auditory nerves; and it is probable that the same elements exist in the *papillæ* of the tongue and skin, to which the nerves of taste and touch are distributed. In these papillæ, the nervous fibres seem to form loops, which are accompanied by similar loops of blood-vessels (Figs. 67 and 68). Hence we may state it as a general fact,

Fig. 67.



Distribution of the tactile nerves at the surface of the lip; as seen in a thin perpendicular section of the skin.

Fig. 68.

Capillary network at margin of lips.

that, wherever a change is to be *originated*, we find *vesicular* matter with capillary blood-vessels; whilst for the *conduction* of such a change to distant parts, the *fibrous* structure is alone required.

382. The connection between the fibrous and vesicular portions of the Nervous system, has not yet been clearly traced. It is quite certain that, as already remarked, many of the nerve fibres which enter a ganglion, come into contact with its cells, passing over or amongst them, and then issuing from it again. And this seems to be the case also with many of the fibres which enter the vesicular matter

of the Spinal cord, and the cortical substance of the brain. Some observations recently made by Dr. Lonsdale on the structure of the nervous system of fœtuses, in which the brain and spinal cord were wanting, present a remarkable confirmation of this view. The nervous cords were for the most part developed; and at their origins (so called), or central extremities, they were found to hang as loose threads in the cavities of the cranium and spine. On examining these threads, it was found that the nerve-tubes of which they consisted formed distinct loops, each of which was composed of a fibre that entered the cavity and then returned from it. These loops were imbedded in granular matter, resembling that interposed between the vesicles in the cortical substance of the brain, and perhaps to be regarded as vesicular substance in an early stage of its formation. All that is known of the laws regulating the formation of irregular productions like these, leads us to the belief, that we may rightly consider this arrangement of the nerve-tubes as one which exists in the nervous centres when they are fully developed. On the other hand, the appearances observed by Messrs. Todd and Bowman appear to indicate, that *some* of the fibres originate directly in the subdivisions of the filamentous prolongations of the nerve-cells; this, however, must still be regarded as an unsettled question.

383. We have now to speak briefly of the Chemical Composition of the Nervous matter;—a consideration which will be presently shown to be of much importance. As formerly remarked (§ 7), the vital activity of a tissue is usually greater, as the proportion of its solid to its fluid contents is less; and this rule holds good most strikingly in regard to the Nervous substance, the vital activity of which is far greater than that of any other tissue, and the solid matter of which usually constitutes no more than a fourth, and occasionally does not exceed an eighth, of its entire weight. The proportion of water is greatest in infancy and least in middle life; and it has been observed to be under the average in idiots. Of the solid matter of the brain, about a third consists of fibrin or albumen; which is probably the material of the membrane of the tubuli, as well as of the tissue that connects them.—It is chiefly with the Fatty matter, which constitutes about a third of the solid substance, that the attention of Chemists has been occupied. This is stated by M. Fremy (one of the most recent analysts) to contain, besides the ordinary fatty matters, and Cholesterine or biliary fat, two peculiar fatty acids, termed the Cerebric and the Oleo-phosphoric. *Cerebric* acid, when purified, is white, and presents itself in crystaline grains. It contains a small proportion of Phosphorus; and differs from the ordinary fatty matter in containing Nitrogen, as also in containing twice their proportion of oxygen. *Oleo-phosphoric* acid is separated from the former by its solubility in ether; it is of a viscid consistence; but when boiled for a long time in water or alcohol, it gradually loses its viscidity, and resolves itself into a pure oil, which is elaine, while phosphoric acid remains in the liquor. The proportion of phosphorus in the brain is

considerable; being from 8 to 18 parts in 1000 of the whole mass, or from 1-20th to 1-30th of the whole solid matter. It seems to be unusually deficient in the brain of idiots.—The remaining third and sometimes more, is composed of a substance termed Osmazome (which seems to be a proteine-compound in a state of decomposition), together with saline matter.—No satisfactory examination has yet been made into the comparative composition of the vesicular and fibrous substances; but according to Lassaigne, the former contains much more water than the latter, and little colourless fat, but nearly 4 per cent. of red fat, which does not exist in the other.

384. Various circumstances lead to the belief, that the Nervous tissue, during the whole period of active life, is continually undergoing changes in its substance, by decay and renewal. We know that, after death, it is one of the first of all the animal tissues to exhibit signs of decomposition; and there is no reason to suppose, that this tendency is absent during life. Hence for the simple maintenance of its normal character, a considerable amount of nutritive change must be required. But many circumstances further lead to the conclusion, that, like all other tissues actively concerned in the vital operations, Nervous matter is subject to a *waste* or *disintegration*, which bears an exact proportion to the activity of its operations;—or, in other words, that every act of the Nervous system involves the death and decay of a certain amount of Nervous matter, the replacement of which will be requisite in order to maintain the system in a state fit for action. We shall hereafter see, that there are certain parts of the Nervous system, particularly those which put in action the respiratory muscles, which are in a state of unceasing, though moderate, activity; and in these, the constant nutrition is sufficient to repair the effects of the constant decay. But those parts, which operate in a more powerful and energetic manner, and which therefore waste more rapidly when in action, need a season of rest for their reparation. Thus a sense of fatigue is experienced, when the mind has been long acting through its instrument—the brain; indicating the necessity for rest and reparation. And when *sleep*, or cessation of the cerebral functions, comes on, the process of nutrition takes place with unchecked energy, counterbalances the results of the previous waste, and prepares the organ for a renewal of its activity. In the healthy state of the body, when the exertion of the nervous system by day does not exceed that, which the repose of the night may compensate, it is maintained in a condition which fits it for constant moderate exercise; but unusual demands upon its powers,—whether by the long-continued and severe exercise of the intellect, by excitement of the emotions, or by the combination of both in that state of *anxiety* which the circumstances of man's condition too frequently induce,—produce an unusual waste, which requires, for the complete restoration of its powers, a prolonged repose.

385. There can be no doubt that (from causes which are not known) the amount of sleep required by different persons, for the

maintenance of a healthy condition of the nervous system, varies considerably; some being able to dispense with it, to a degree which would be exceedingly injurious to others of no greater mental activity. Where a prolonged exertion of the mind has been made, and the natural tendency to sleep has been habitually resisted, by a strong effort of the will, injurious results are sure to follow. The bodily health breaks down, and too frequently the mind itself is permanently enfeebled. It is obvious that the nutrition of the Nervous system becomes completely deranged; and that the tissue is no longer formed, in the manner requisite for the discharge of its healthy functions.

386. As the amount of Muscular tissue that has undergone disintegration, is represented (other things being equal) by the quantity of urea in the urine, so do we find that an unusual waste of the *nervous* matter is indicated by an increase in the amount of *phosphatic* deposits. No others of the soft tissues contain any large proportion of phosphorus; and the marked increase in these deposits, which has been continually observed to accompany long-continued *wear* of mind, whether by intellectual exertion, or by anxiety, can scarcely be set down to any other cause. The most satisfactory proof is to be found in cases, in which there is a periodical demand upon the mental powers; as, for example, among clergymen, in the preparation for, and discharge of, their Sunday duties. This is found to be almost invariably followed by the appearance of a large quantity of the phosphates in the urine. And in cases in which constant and severe intellectual exertion has impaired the nutrition of the brain, and has consequently weakened the mental power, it is found that any premature attempt to renew the activity of its exercise, causes the re-appearance of the excessive phosphatic discharge, which indicates an undue waste of nervous matter.

387. As the disintegration of the Nervous System is thus proportional to its exercise, so must its reparation make a corresponding demand upon the nutritive processes. And accordingly we find, that it is very copiously supplied with blood-vessels; and that the amount of food appropriated to its maintenance in an active condition, is very considerable. This we know from the fact, that persons of active minds, but sedentary bodily habits, commonly require nearly as much food as those in whom the waste of the Muscular system is greater, and that of the Nervous system less, in virtue of their bodily activity and the less energetic operation of their minds.

388. The first development of the nerve-fibres appears to take place, like that of Muscular fibre, by the coalescence of a number of primary cells into a continuous tube; the granular fatty matter within being the product of a subsequent secreting-action. The nuclei of the original cells may be frequently seen in the nerve-tubes at a later period, lying between their membranous walls and the substance deposited in their interior. It is probable that the nerve-tubes undergo little change, from the period of their first production to

that of their final decay; their function, as will be presently shown, being of a much more *passive* character, than that of the vesicular substance. On the other hand, the vesicular matter appears to be in a state of continual change, as is the case with all cells whose functions are active. The appearances observed by Henle in the cortical substance of the brain lead to the belief, that there is as continual a succession of nerve-cells as there is of epidermic cells; their development commencing at the surface, where they are most copiously supplied with blood-vessels from the investing membrane, and proceeding as they are carried towards the inner layers, where they come into more immediate relation with the fibrous portion of the nerve-structure. This change of place is probably due to the continual death and decay of the mature cells, where they are connected with the fibres; and the constant production of new generations at the external surface,—thus carrying the previously-formed cells inwards, in precisely the same manner that the epidermic cells are progressively carried outwards.

389. The *regeneration* of Nervous tissue that has been destroyed, takes place very readily in continuity with that which is left sound. This may be more easily proved by the return of the sensory and motor endowments of the part, whose nerves have been separated, than by microscopic examination of the reunited trunks themselves, which is not always satisfactory. All our knowledge of the functions of the nervous system leads to the belief, that *perfect continuity* of the nerve-tubes is requisite for the conduction of an impression of any kind,—whether this be destined to produce motion or sensation; and various facts, well known to Surgeons, prove that such restoration may be complete. In the various operations which are practised for the restoration of lost parts, a portion of tissue removed from one spot is grafted, as it were, upon another; its original attachments are more or less completely severed,—frequently entirely destroyed,—and new ones are formed. Now in such a part, as long as its original connections exist, and the new ones are not completely formed, the sensation is referred to the spot from which it was taken; thus when a new nose is made, by partly detaching and bringing down a piece of skin from the forehead, the patient at first feels, when anything touches the tip of his nose, as the contact were really with his forehead. After time has been given, however, for the establishment of new connections with the parts, into whose neighbourhood it has been brought, the old connections of the grafted portion are completely severed; and an interval then ensues, during which it frequently loses all sensibility; but after a time its power of feeling is restored, and the sensations received through it are referred to the right spot.—A more familiar case is the regeneration of Skin, containing sensory nerves, which takes place in the well-managed healing of wounds involving loss of substance. Here there must obviously be, not merely a prolongation of the nerve-tubes from the subjacent and surrounding trunks, but also a formation of new sen-

sory papillæ.—A still more striking example of the regeneration of Nervous tissue, however, is to be found in those cases (of which there are now several on record), in which portions of the extremities, that have been completely severed by accident, have been made to adhere to the stump, and have in time completely recovered their connection with the Nervous as with the other systems,—as indicated by the restoration of their sensory and motor endowments.—Of the degree in which the vesicular substance of the Nervous system may be regenerated, we have no certain knowledge; but there can be little doubt, from the activity of its usual nutritive changes, that a complete reproduction may be effected in cases of loss of substance, where it can commence from a neighbouring mass of the same tissue.

390. We have now to inquire into the conditions under which the peculiar properties of the Nervous System are manifested in an active form; and it will first be desirable to explain, somewhat more in detail, the nature of the different operations to which it is subservient. These operations present themselves, in their most complex form, in Man and the higher animals; but they may often be most satisfactorily studied in the lower. In the first place, when an *impression* is made upon any part of the surface of the body by mechanical contact, by heat, electricity, or any other similar agent, —or upon the organs of special sense (the eye and ear, the nose and tongue), by light or sound, by odorous or sapid bodies,—these impressions, in the healthy and wakeful state of the Nervous system are *felt* as *sensations;* that is, the mind is rendered conscious of them. Now there can be no doubt that the mind is immediately influenced, not by the impression in the remote organ, but by a certain change in the condition of the brain, excited or aroused by that which has originated elsewhere. For if the communication with the brain be cut off, no impression on the distant parts of the nervous system is felt, notwithstanding that the mind remains perfectly capable of receiving it. The mind, then, is only rendered conscious of external objects by the influence which they exert upon the *brain*, or upon a certain part of it, which, being the peculiar seat of sensation, is called the *sensorium.* Hence we recognize, in the process by which the mind is rendered conscious of external objects, three distinct stages;—first, the reception of the impression at the extremities of the sensory nerve; second, the conduction of the impression, along the trunk of the nerve, to the sensorium; third, the change excited by it in the sensorium itself, through which sensation is produced. Here, then, the change in the condition of the nervous system commences at the circumference, and is transmitted to the centre; and the fibres which are concerned in this transmission are termed *sensory.*

391. On the other hand, when an emotion, an instinctive impulse, or an act of the will, operates through the brain to produce a muscular contraction, the first change is in the condition of the brain itself or of

a certain part of it. The influence of this change is transmitted by the motor nerves to the muscles, among which they are distributed; and the desired movement is the result. Here, too, we have three stages; first, the origination of the change by the act of the mind upon the brain; second, the conduction of that change along the motor nerves; and third, the stimulation of the muscles to contraction. But the operation here commences at the centre; and the effects of the change in the brain are transmitted to the circumference, by a set of nervous fibres which are termed *motor*. The complete distinctness of these two classes of fibres was first established by Sir C. Bell. It is best seen in the nerves of the head, of which some are purely sensory, and others purely motor; but it may also be clearly proved to exist at the *roots* of the spinal nerves (although their *trunks* possess mixed endowments), the posterior being sensory, whilst the anterior are motor.

392. But although sensations can only be felt through the *brain*, and voluntary motions can only be produced by an action of the mind through the same organ, yet there are many changes in the animal body, in which the nervous system is concerned, which yet do not involve the operation of the brain, being produced without our consciousness being necessarily excited, and without any act of the will, or even in opposition to its efforts. Of these actions, the spinal cord of Vertebrata, and its prolongation within the cranium, are the chief instruments; in the Invertebrate animals, they are performed by various ganglia, which are usually disposed in the neighbourhood of the organs to which they minister. If the spinal cord of a Frog be divided in its back, above the crural plexus, so as entirely to cut off the nerves of the lower extremities from connection with the brain, the animal loses all voluntary control over these limbs, and no sign of pain is produced by any injury done to them. But they are not thereby rendered motionless; for various stimuli applied to the limbs themselves will cause movements in them. Thus if the skin of the foot be pinched, or if a flame be applied to it, the leg will be violently retracted. Or, if the cloaca be irritated by a probe, the feet will endeavour to push away the instrument. We have no reason hence to believe, that the animal feels the irritation, or intends to execute these movements, in order to escape from it; for motions of a similar kind are exhibited by men, who have suffered injury of the lower part of the spinal cord, and who are utterly unconscious, either of the irritation, or of the action their limbs perform.

393. We are not to suppose, however, that the stimulus acts at once upon the muscles, without the nervous system being concerned at all; throwing them into contraction by its direct influence. For it is quite certain that, unless the nervous trunks remain continuous with the spinal cord, and unless the part of the spinal cord with which they are connected remains sound (although cut off from connection with the parts above, and with the brain), no action will be the result. If the trunks be divided, or *either* of the roots by which they are con-

nected with the spinal cord be severed, or the lower portion of the spinal cord itself be injured, no stimulation will cause the muscular movements just described. A very good example of the necessity of the completeness of the nervous trunks, which convey impressions *to* and *from* the central organ, is found in the movements of the iris, for the contraction and dilatation of the pupil. Here, the stimulus of light upon the retina gives rise to a change in the condition of the optic nerve ; which, being transmitted to a certain portion of the encephalon with which that nerve is connected, excites there a motor impulse ; and this impulse is conveyed through a distinct nerve (a branch of the third pair) to the iris, occasioning contraction of the pupil. Every one knows that this adjustment of the size of the pupil to the amount of light, is effected without any exertion of the will on his own part, and even without any consciousness that it is taking place. It is performed, too, during profound sleep ; when the influence of light upon the retina excites no consciousness of its presence, —when no sensation, therefore, is produced by it.

394. The class of actions thus performed, is termed *reflex;* and we see that every such action involves the following series of changes. In the first place, an impression is made upon the extremity of a nerve, by some external agent ; just as when sensation is to be produced. Secondly, this impression is transmitted by a nervous trunk to the spinal cord in Vertebrata, or to some ganglionic mass which answers to it in the Invertebrata. But instead of being communicated by its means to the mind, and becoming a sensation, it immediately and necessarily executes a motor impulse ; which is *reflected* back as it were to certain muscles, and by their contraction, gives rise to a movement. We shall hereafter see, that nearly all those movements in the animal body, which are immediately connected with the maintenance of the organic functions, such as those of respiration, deglutition (or swallowing), the expulsion of the feces, urine and fœtus, &c.—are performed in this manner.

395. Now there is no reason to believe, that the mode in which impressions are conducted by the nervous trunks, whether towards or from the nervous centres, is in any way different from that which takes place, when sensations are to be produced, or voluntary motions executed. The endowments of the *trunks* appear to be the same in both instances ; but those of the *centres* are different. We shall hereafter see, that the very same trunks contain fibres, originating at the same part of the surface, of which some go to the brain, and others to the spinal cord ; impressions on the former, therefore, will produce sensations, whilst similar impressions on the latter will give rise to no sensations, but will excite a motor influence in *immediate* respondence to their call. Again, the motor fibres which pass forth from the spinal cord, and which convey the reflex influence created by its vesicular substance, are bound up in the same trunk with others, which proceed from the brain, and which convey the influence of the will, communicated through *its* gray or vesicular matter. Thus we have at least

two sets of fibres conveying impressions *inwards* or *centripetally;* one of them being *sensory* (as already explained § 390) in virtue of its connection with the brain; whilst the other is *excitor*, or destined to excite reflex movements, through the spinal cord. These, taken collectively, may be termed *afferent* or *centripetal* fibres. On the other hand, there are at least two sets of fibres conveying motor impulses to the muscles; one of them communicating the influence of the mind, operating through the brain; whilst the other merely transmits the reflex power of the spinal cord. These in conjunction may be called *efferent* or centrifugal fibres. The following diagram may assist the Student in comprehending the relations of the elementary parts of the Nervous System.

396. Of the mode by which the effects of changes in one part of the Nervous System, are thus instantaneously transmitted to another, nothing whatever is known. There is evidently a strong analogy between this phenomenon, and the instantaneous transmission of the

Fig. 69.

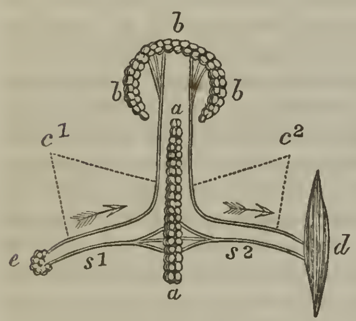


Diagram of the origins and terminations of the different groups of nervous fibres;—*a*, *a*, vesicular substance of the spinal cord; *b*, *b*, *b*, vesicular substance of the brain; *e*, vesicular substance at the commencement of afferent nerve, which consists of, *c*1, the cerebral division, or sensory nerve, passing on to the brain, and *s*1, the spinal division, or excitor nerve, which terminates in the vesicular substance of the spinal cord; on the other side we have the efferent or motor nerve proceeding to the muscle *d*, likewise consisting of two divisions,—*c*2, the cerebral portion, proceeding from the brain, and conveying the influence of the will or of instinct; and *s*2, the spinal division, conveying the reflex power of the spinal cord.

Electric power along good conductors; and there is this further analogy between the Nervous and Electric agencies, that the latter will produce many of the effects of the former. Thus a very feeble galvanic current transmitted along a motor nerve, serves to excite contractions in the muscles supplied by it; and in like manner, a galvanic current transmitted along any of the sensory nerves, gives rise to a sensation of the kind to which the nerve ministers. Moreover, we shall hereafter see, that certain animals are capable of generating Electric power in a very remarkable manner (Chap. X.); and that the nervous system is in some way essentially concerned in this operation. But on the other hand, it is quite certain that the influence transmitted along the nerves of the living body is *not* ordinary electricity; for all attempts to procure manifestations of electric changes in the state of nerves, that are acting most energetically on muscles, have completely failed; and a nerve remains capable of conveying the influence of electricity, when it has been rendered unable to transmit the influence of the brain,—as by tying a ligature

round it, or by tightly compressing it between the forceps, which gives no interruption to the one agency, whilst it completely checks the other.—Notwithstanding, then, the strong *analogy* which exists between these two powers, we are *not* warranted in regarding them as *identical;* although it is very possible that the Nervous power may be in time shown (as Magnetism has been proved) to be a peculiar modification of ordinary Electricity, acting under circumstances in many respects dissimilar, and therefore appearing to possess distinct properties.

397. It is more desirable, however, that we should understand the conditions under which the phenomena of the Nervous system take place, than that we should spend much time in discussing the identity of its peculiar powers with any others in Nature. The *conducting* power of the nervous fibres appears to remain with little decrease for some time after death, especially in cold-blooded animals; for we can, by pinching, pricking, or otherwise stimulating the motor trunks, give rise to contractions in the muscles supplied by them, exactly as during life. This power is much lessened by the influence of narcotics; so that if a nervous trunk be soaked in a solution of opium, belladonna, or other powerful narcotic, it ceases to be able to convey the effects of stimuli to the muscles, some time before the muscles themselves lose their contractile power. On the other hand, it seems to be exalted by various irritating influences; so that, when the nervous trunk has been treated with strychnia, or when it has been subjected to undue excitement in other ways, a very slight change is magnified (as it were) during its transmission, and produces effects of unusual intensity.

398. Now although the conducting power of the fibrous structure will continue for a time, after the circulation through it has ceased, the peculiar endowments of the vesicular substance, by which it *originates* the changes which the former transmits, are *only* manifested, when blood is moving through its capillaries. Thus if the circulation through the brain cease but for a moment, total insensibility, and loss of the power of voluntary motion, immediately supervene. The brain is supplied with blood through four arteries,—the two internal carotids, and the two vertebrals; and by the communication of these with each other through the *circle of Willis*, the circulation will still be kept up, if only one of them should convey blood into the cavity of the cranium. Hence it is necessary that the flow of blood should be checked through *all* of them, in order that the functions of the brain should be suspended; and the suspension is then complete and instantaneous. The best method of effecting this was devised by Sir Astley Cooper. He tied both the carotid arteries in a dog; which, for the reason just mentioned, did not produce any decided influence on the functions of the brain, the circulation being kept up through the vertebrals. But upon compressing the latter, so as to suspend the flow of blood through them, *immediate* insensibility, and loss of voluntary power, were the result. When the compression was taken

off, the animal immediately returned to its usual state; and again became suddenly insensible, when the pressure was renewed. Although the functions of the brain were thus suspended, those of the spinal cord were not; as was shown by the occurrence of convulsive movements. But in the state called *Syncope*, or fainting, the suspension of the circulation, by a failure in the heart's action, causes an entire loss of power in both these centres; and a complete cessation of muscular movement is the result. This condition may come on instantaneously, under the influence of powerful mental emotion, or of some other cause, which act *primarily* in suspending the heart's action, and consequently in checking the circulation; the insensibility, and loss of muscular power, are *secondary* results, depending upon the suspension of the powers of the nervous centres, consequent upon the cessation of the flow of blood through them.

399. The due activity of the vesicular nervous matter is not only dependent upon a sufficient supply of blood, but it requires that this blood should be in a state of extreme purity; for there is no tissue in the body, whose functions are so readily deranged, by any departure from the regular standard in the circulating fluid,—whether this consist in the alteration of the proportions of its normal ingredients, or in the introduction of other substances which have no proper place in it. One of the most fertile sources of disturbance in the action of the brain, consists in the retention of substances within the blood, which ought to be excreted from it. We shall hereafter see, that three of the largest and most important organs in the body,—the lungs, the liver, and the kidneys,—have it for their special office, to separate from the circulating fluid the products of the decomposition, which is continually taking place in the body; and thereby to maintain its purity, and its fitness for its important functions. Now if these, from any cause, even partially fail in their office, speedy disturbance of the functions of the nervous centres is the result. Thus if the lungs do not purify the venous blood of its impregnation of carbonic acid, or restore to it the proper proportion of oxygen, the functions of the brain are seriously affected. The sensations become indistinct, the will loses its control over the muscles, giddiness and faintness come on, and at last complete insensibility supervenes. Corresponding symptoms occur, though to a less serious degree, when the excretion of carbonic acid is but slightly impeded. Thus when a number of persons are shut up in an ill-ventilated apartment, for a sufficient length of time to raise the proportion of carbonic acid in the air to 1 or 2 per cent, the continued purification of their blood by respiration is but insufficiently performed, for reasons which will be stated hereafter (Chap. VIII.); and the carbonic acid accumulates in their blood in a sufficient degree, to produce headache and obtuseness of the mental powers.—Similar results take place, as will be shown hereafter, from the retention of the substances, which ought to be drawn off by the liver and kidneys; these, when they accumulate in even a trifling degree, produce torpor of the functions of the brain;

and, when their proportion increases, complete cessation of its powers is the result, their action being precisely that of narcotic poisons. Various substances introduced into the blood may exert similar influences; depressing the activity of the vesicular substance of the nervous centres, and consequently producing torpidity, not merely in regard to the reception of impressions, and the performance of voluntary motions, but also in the mental operations generally.

400. On the other hand, various conditions of the blood, especially those depending on the presence of certain external agents, produce an undue energy in the functions of the nervous centres; which energy, however, is almost invariably accompanied by irregularity, or want of balance among the different actions. Of this we have a familiar example in the operation of alcohol. Its first effect, when taken in moderate quantity, is usually to produce a simple increase in the activity of the cerebral functions. A further dose, however, occasions not merely an increase, but an irregularity; destroying that power of self-control, which is so important a means of balancing the different tendencies in the healthy condition of the mind. And a still larger dose has the effect of a narcotic poison; producing diminution or suspension of activity in all the functions of the brain. In some persons, this is the mode in which the alcohol acts from the first,—its stimulating effects being altogether wanting. —A similar activity is usually produced by the respiration of the nitreous oxide; which seems to increase all the powers of the mind, save that of self-control, which it diminishes; the individual, while under its influence, being the slave of his impulses, which act on his muscular system with astonishing energy. Very analogous to this, is the incipient stage of mania, which is simply an undue energy of the cerebral functions, at first in some degree under the control of the will, but afterwards increasing to an extent that renders the individual completely powerless over himself; and showing itself in the intensity of the sensations produced by external objects, in the vividness of the trains of thought, (which, being entirely uncontrolled, succeed each other with apparent irregularity, though probably according to the laws of association and suggestion,) and in the violence of the muscular actions. Such a state may continue for some time, without the intervention of sleep; but the subsequent exhaustion of nervous power is proportioned to the duration of the excitement; and frequent attacks of mania almost invariably subside at last into imbecility.

401. In these cases of undue excitement, there is obviously an increase in the supply of blood to the head, as indicated by the suffusion of the face, the injection of the conjunctiva, the throbbing at the temples, the pulsation of the carotids; and we find that measures which diminish the activity of the circulation through the brain are those most effectual in subduing the excitement. But it does not at all follow, that this undue action of the brain should be connected with an *excess* in the whole amount of nutritive material, and should

require general depletion for its treatment. In fact, a very similar class of symptoms may present itself under two conditions of an entirely opposite kind,—*inflammation*, accompanied with an increase in the proportion of fibrin in the blood, and requiring treatment of a lowering kind,—and *irritation*, depending on a state of blood in which there is a deficiency of solid materials, and requiring a strengthening and even a stimulating regimen. The skill of the practitioner is often put to the test, in the due discrimination between these states.

402. The preceding examples mark the influence of various causes upon the actions of the vesicular matter of the *brain;* others might be adduced to show that the vesicular substance of the *spinal cord* is also liable to have its powers depressed or excited; but these will be best adverted to hereafter, when the distinct functions of that organ are under consideration (Chap. XII.). We may simply notice, that the stimulating effect of Strychnia is peculiarly and most remarkably exerted upon the vesicular substance of the spinal cord; and that a corresponding state, in which violent convulsive actions are excited by the most trifling causes, sometimes presents itself as a peculiar form of disease, named Tetanus, which may be either *idiopathic*, depending probably upon a disordered condition of the blood, or *traumatic*, consequent upon the irritation of a wound.

403. But, as formerly remarked, it is not in the Nervous *centres* only that changes originate. Whenever an impression is made upon the surface of the body, or upon the organs of special sense, which, being conducted to the nervous centres, either excites a sensation in the brain (§ 390), or a reflex action through the spinal cord (§ 392), the reception and propagation of such impression at the *extremities* of the sensory nerve requires a set of conditions of the same kind with those which we have seen to exist in the nervous centres. In fact, if we regard the course of the *motor* nerves as commencing in the nervous centres and terminating in the muscles, we may with equal justice consider that of the *sensory* nerves as originating in their peripheral extremities, and terminating in the sensorium. And, as already stated (§ 381), precisely the same kind of vesicular structure exists in some (probably in all) of the peripheral expansions of the sensory nerves as makes up the gray substance of the brain and spinal cord. Now it is easily shown, that the circulation of blood through these parts is just as necessary for the original reception of the impressions, as is the circulation through the brain to their reception as sensations, and to the origination of motor impulses by an act of the will. We find that anything which retards the circulation through a part supplied by sensory nerves, diminishes its sensibility; and that if the flow of blood be completely stagnated, entire insensibility is the result. A familiar example of this is seen in the effects of prolonged cold, which, by diminishing, and then entirely checking, the flow of blood through the skin, produces first numbness, and then complete insensibility of the part. This result, how-

ever, may be partly due to the direct influence of the cold upon the nerve-vesicles themselves, depressing their peculiar vital powers (§ 97). The same effect is produced, however, when the supply of blood is checked in any other way; as, for example, by pressure on the artery, or by obstruction in its interior. Thus, when the main artery of a limb is tied, numbness of the extremities is immediately perceived; and this continues until the circulation is re-established by the collateral branches, when the usual amount of sensibility is restored. Again, in the gangrene which depends upon obstruction of the arterial trunks by a fibrinous clot in their interior, diminution of sensibility, consequent upon the insufficient circulation, is one of the first symptoms.

404. On the other hand, increased circulation of blood through a part produces exaltation of its sensibility; that is, the ordinary impressions produce changes of unusual energy in its sensory nerves. This is particularly evident in the increased sensibility of the genital organs of animals during the period of heat; and in those of Man, when in a state of venereal excitement. Moderate warmth, friction, exercise, and other causes which increase the circulation through a part, also augment its sensibility; and this augmentation is one of the most constant indications of that state of *determination of blood*, or *active congestion*, which usually precedes inflammation, and which exists in the parts surrounding the centre of inflammatory action. But it must be borne in mind, here as elsewhere (§ 401), that such exaltation of function in a limited part, is quite consistent with general debility; and in fact we may often observe, that the tendency to such local affections is particularly great, when the blood is in a very poor condition. (See Chap. V.)

405. To sum up, then, we may compare the vesicular substance, wherever it exists, to a galvanic combination: the former being capable of generating nervous influence, and transmitting it along the fibrous structure, to the part on which it is to operate; in the same manner as the latter generates electric power, and transmits it along the conducting wires, to the point at which it is to effect a decomposition or any other change. In one of the most perfect forms of the galvanic battery (that invented by Mr. Smee), although the metals remain inserted in the acid solution, and are consequently always ready for action, no electricity is generated until the circuit is complete; and the *waste* of the zinc produced by its solution in the acid, is therefore exactly proportional to the electric effects to which it gives rise. The condition of the nervous system, in the healthy and waking state, bears a close analogy to this; for it is in a state constantly ready for action, but waits to be excited; and its waste is proportional to the activity of its function. The vesicular matter, diffused over the surface of the body, is inactive, until an impression is made upon it by some external agent; but a change then takes place in its condition (of which we know no more, than that the presence of arterial

blood and a certain amount of warmth are necessary for it), which is transmitted to the central organs by the sensory trunks. It would appear that the excitement of this change has a tendency to increase the afflux of blood to the part; thus when a lozenge or some similar substance is allowed to lie for a time in contact with the tongue, or with the side of the mouth, a roughness is produced, which is due to the erection of the sensory papillæ, by the distension of their blood-vessels. On the other hand, the change in the vesicular matter of the central organs, by which motion is produced in the distant muscles, may be excited either by the stimulus conveyed by the afferent nerves (as in reflex action, § 392), or by an act of *Mind*. This act may be voluntary, originating in the will; or it may be instinctive or emotional, resulting from certain states of mind excited by sensations, and altogether independent of the will. Of the mode in which the mind thus acts upon the nervous system, we know nothing whatever, and probably never shall be informed in our present state of being. But it is sufficient for us to be aware of the physiological *fact* of the peculiar connection between the mind and the brain; a connection so intimate, as to enable the mind to receive through the body a knowledge of the condition of the Universe around it, and to impress on the body the results of its own determinations; and of such a nature, that the regularity of the working of the mind itself is dependent upon the complete organization of the brain in the first instance, upon the constant supply of pure and well-elaborated blood, and upon all those influences which favour the due performance of the nutritive operations in general.

BOOK II.

SPECIAL PHYSIOLOGY.

CHAPTER IV.

OF FOOD, AND THE DIGESTIVE PROCESS.

1. *Sources of the Demand for Aliment.*

406. The dependence of all Organized beings upon food or aliment, must be evident from the facts stated in the preceding portion of this Treatise. In the first place, the germ requires a large and constant supply of materials, with which it may develop itself into the perfect being, by the properties with which it is endowed. In all but the lowest tribes of Plants, we find the materials required for the earliest stages of the process prepared and set apart by the parent. Thus in the *seed*, the germ itself forms but a small proportion of the whole substance, the principal mass being composed of starchy matter, which is laid up there for its nutrition; and the act of germination consists in the appropriation of that nutriment by the germ, and the consequent development of the latter, up to the point at which it becomes independent of such assistance, and is able for itself to procure, from the soil and atmosphere that surround it, the materials for its continued growth. So in the *egg* of the Animal, the principal mass is composed of Albumen and oily matter; the germ itself being, at the time the egg is first deposited, a mere point invisible to the naked eye; these materials serve as the food or aliment of the germ, which gradually draws them to itself, and converts them into the materials of its own structure, and at the end of a certain period the young animal comes forth from the egg ready to obtain for itself the food which is necessary for its continued increase in size.

407. In many instances among the lower animals, the form in which the young animal emerges from the egg is very different from that which it is subsequently to assume; and the latter is only attained by a process of *metamorphosis*. This change has been longest known, and most fully studied, in the case of Insects and Frogs; which

were formerly thought to constitute an exception to all general rules in this respect,—the Insect coming forth from the egg in the state of a Worm, and the Frog in the condition of a Fish. But it is now known that changes of form, as complete as these, occur in a large proportion of the lower tribes of Animals; so that the *absence* of them is the exception. The fact seems to be, that the supply of nutriment laid up within the egg, among the lower classes, is by no means sufficient to carry on the embryo to the form it is subsequently to attain; and its development is so arranged that it may come into the world in a condition which adapts it to obtain its own nutriment, and thus to acquire for itself the materials of its further development. Thus the Insect, in its *larva* or Caterpillar state, is essentially a fœtus in regard to its grade of development; but it is a fœtus capable of acquiring its own food. In this condition it attains its full growth as regards *size*, though its *form* remains the same; but it then, in passing into the Chrysalis state, reassumes (as it were) the condition of an embryo within the egg,—the development of various new parts takes place, at the expense of the nutriment stored up in its tissues,—and it comes forth as the perfect insect. In many of the lower tribes, the animal quits the egg at a still earlier period in comparison; thus it has been lately shown by M. Milne Edwards, that some of the long marine worms consist only of a single segment, forming a kind of head, when they leave the egg; and that the other segments, to the number, it may be, of several hundred, are gradually developed from this, by a process that resembles the budding of Plants.

408. Up to the period, then, when the full dimensions of the body have been attained, and the complete evolution of all its organs has taken place, a due supply of food is necessary for these purposes. In the Plant nearly the whole of the alimentary materials taken into the system, are thus appropriated; the extension of its structure going on almost indefinitely, and the waste occasioned by decay being comparatively small. Thus the carbon, which is given out by the respiratory process in the form of carbonic acid, bears but a small proportion to that, which is introduced by the decomposition of that same gas, under the influence of light (§ 81). And the fall of the leaves, which takes place once a year or more frequently, and which gives back a large quantity of the matter that has undergone the organizing process, does not occur, until by their means a considerable addition has been made to the solid and permanent substance of the tree.

409. This is not the case, however, with the Animal. Its period of *increase* is limited. The full size of the body is usually attained, and all the organs acquire their complete evolution at a comparatively early period. The continued supply of food is not then requisite for the extension of the structure, but simply for its maintenance; and the source of the demand lies in the constant *waste*, to which, during its period of activity, it is subjected. We have seen that every action of the Nervous and Muscular systems involves the death and decay of a certain amount of the living tissue,—as indicated by the appearance of

the products of that decay in the Excretions; and a large part of the demand for food will be consequently occasioned by the necessity for making good the loss thus sustained. Hence we find that the demand for food bears a close relation to the activity of the animal functions; so that a diet, which would be superfluous and injurious to an individual of inert habits, is suitable and beneficial to one who is leading a life of continual exertion; and this difference manifests itself in the requirements of the same individual who makes a change in his habits, —the indolent man acquiring an appetite by vigorous exertion, and the active man losing his disposition to hearty feeding by any cause that keeps him from his accustomed exercise. We see precisely the same contrast between Animals of different tribes, whose natural instincts lead them to different modes of life. The Birds of most active flight, and the Mammals which are required to put forth the greatest efforts to obtain their food, need the largest and most constant supplies of nutriment; but even the least active of these classes stand in remarkable contrast with the inert Reptiles, whose slow and feeble movements are attended with so little waste, that they can sustain life for weeks and even months, with little or no diminution of their usual activity, without a fresh supply of food.

410. The waste and decay just adverted to, however, do not affect the muscular and nervous tissues alone; for all the operations of nutrition involve it to a certain extent. It has been already shown that the acts of absorption, assimilation, respiration, secretion, and reproduction,—all those, in fact, by which the material for the nutrition of the nervous and muscular tissues is first prepared, and subsequently maintained in the requisite purity,—are effected in the Animal, as in the Plant, by the agency of cells, which are continually dying and requiring renewal. In most Vegetables, the death of the parts concerned in these functions takes place simultaneously, as soon as they have performed them; the whole crop of leaves ceasing at once to perform its proper actions, and dropping off;—to be replaced by another, at an interval that solely depends upon the temperature under which the tree is living (§ 99). In the evergreen, however, the process bears a close resemblance to that which we observe in the Animal; for the leaves die one by one, and not simultaneously; and are constantly undergoing replacement, so that the vigour of the system and the activity of its nutritive processes never suffer a complete suspension.

411. In the Animal body, the different classes of cells, to which allusion has been made, are in like manner constantly undergoing death and renewal; and this with a rapidity proportioned to the energy of their functions. Hence a supply of food is as requisite to furnish the materials of their growth, as it is in Plants to furnish the materials of the growth of the leaves. A large part of these materials are subsequently used for other purposes in the economy; thus, as the leaves prepare the sap which is to nourish the woody stem, and to form new shoots, so do the absorbing and assimilating cells prepare

and furnish the fluid elements of the blood, which are to repair the waste of nerve and muscle, bone and cartilage, &c. But still a considerable amount is expended in the simple nutrition of these organs themselves, whose duration is transient, and whose solid parts are cast off as of no further use. Thus the skin and all the mucous surfaces are continually forming and throwing off epidermic and epithelial cells, whose formation requires a regular supply of nutriment; and only a part of this nutriment (that which occupies the *cavity* of the cells) consists of matter, that is destined to serve some other purpose in the system, or that has already answered it; the remainder (that of which the solid walls are composed) being furnished by the nutritive materials of the blood, and being henceforth altogether lost to it.—Thus every act of Nutrition involves a waste or decay of Organized tissue.

412. We may observe a marked difference, however, between the amount of aliment required, and the amount of waste occasioned, by the simple exercise of the *nutritive* or *vegetative* functions in the building-up and maintenance of the animal body, and that which results from the exercise of the *animal* functions. The former are carried on, with scarcely any intermixture of the latter, during fœtal life. The aliment, in a state of preparation, is introduced into the fœtal vessels; and is conveyed by them into the various parts of the structure, which are developed at its expense. The amount of *waste* is then very trifling, as we may judge by the small amount of excretory matter, the product of the action of the liver and kidneys, which has accumulated at the time of birth; although these organs have attained a sufficient development to act with energy when called upon to do so. But as soon as the *movements* of the body begin to take place with activity, the waste increases greatly; and we even observe this immediately after birth, when a large part of the time is still passed in sleep, but when the actions of respiration involve a constant employment of muscular power.—In the state of profound *sleep*, at subsequent periods of life, the vegetative functions are performed, with no other exercise of the animal powers, than is requisite to sustain them; and we observe that the waste, and the demand for food, are then diminished to a very low point. This is well seen in many animals, which lead a life of great activity during the warmer parts of the year, but which pass the winter in a state of profound sleep, without, however, any considerable reduction of temperature; the demand for food, instead of being frequent, is only felt at long intervals, and the excretions are much reduced in amount. And those animals which become completely inert, either by the influence of cold, or by the drying-up of their tissues, do not suffer from the prolonged deprivation of food; because not only are their animal functions suspended, but their nutritive operations also are in complete abeyance; and the continual decomposition of their tissues, which would otherwise be taking place, is checked by the cold or desiccation; so that the whole series of changes which goes on in their active condition is completely at a stand.

413. But there is another most important cause of demand for food, amongst the higher Animals, which does not exist either amongst the lower Animals, or in the Vegetable kingdom. We have seen (Chap. II.) that Mammals and Birds, and to a certain extent Insects also, are able to sustain the heat of their bodies at a fixed standard, and thus to be independent of variations in external temperature. This they are enabled to do, as will be explained hereafter, by a process strictly analogous to ordinary combustion; the carbon and hydrogen directly supplied by their food, or after having been employed for a time in the composition of the living tissues and then set free, being made to unite with oxygen introduced by the respiratory process, and thus giving off the same heat as if the same materials were burned in a furnace. And it has been further shown, that the immediate cause of death in a warm-blooded animal, from which food has been entirely withheld, is the inability any longer to sustain the temperature, which is requisite for the performance of its vital operations (§ 117). Hence we see the necessity for a constant supply of aliment, in the case of warm-blooded animals, for this purpose alone; and the demand will be chiefly regulated by the external temperature. When the heat is rapidly carried off from the surface, by the chilling influence of the surrounding air, a much greater amount of carbon and hydrogen must be consumed within the body, to maintain its proper heat, than when the air is nearly as warm as the body itself; so that a diet which is appropriate to the former circumstances, is superfluous and injurious in the latter; and the food which is amply sufficient in a warm climate, is utterly destitute of power to enable it to resist the influence of severe cold. This is a fact continually experienced; both in the ordinary recurrence of changes of temperature in our own climate; and, still more remarkably, when the same individual is subjected to the extremes of heat and cold, in successively visiting the tropical and frigid zones.

414. Thus we find that in the Animal body, aliment is ordinarily required for four different purposes. *First*, for the original construction or building-up of the organism. *Second*, to supply the loss occasioned by its continual decay, even when in a state of repose. *Third*, to compensate for the waste occasioned by the active exercise of the nervous and muscular systems. And *Fourth*, to supply the materials for the heat-producing process, by which the temperature of the body is kept up.—The amount required for these several purposes will vary according to the conditions of the body, as regards exercise or repose, and external heat or cold. It is also subject to great variation with difference of *age*. During the period of growth, it might be anticipated that a larger supply of food would be required, than when the full stature has been attained; but a very small daily addition would suffice in the case of a child or youth, to produce the entire increase of a whole year. Yet every one knows that the child requires *much* more food than the adult, in proportion to his comparative bulk. This results from the much more rapid *change* in the

constituents of his body; which is evident from the large proportional amount of his excretions, from the quickness with which the effects of illness or of deficiency of food manifest themselves in the diminution of the bulk and firmness of the body, from the short duration of life when food is altogether withheld, and from the readiness with which losses of substance by disease or injury are repaired, when the nutritive processes are restored to their full activity. The converse of all this holds good in the aged person. The excretions diminish in amount, the want of food may be sustained for a longer period, losses of substance are but slowly repaired, and everything indicates that the interstitial changes are performed with comparative slowness; and, accordingly, the demand for food is far less in proportion to the bulk of the body than it is in the adult, and may be even absolutely less than in the child of a fourth of its weight.

415. The demand for food is increased by any cause, which creates an unusual *drain* or *waste* in the system. Thus an extensive suppurating action can be sustained only by a large supply of highly-nutritious food. The mother, who has to furnish the daily supply of milk which constitutes the sole support of her offspring, needs an unusual sustenance for this purpose. And there are states of the system, in which the solid tissues seem to possess an unusual tendency to decomposition, and in which an increased supply of aliment is therefore required. This is the case, for example, in diabetes; one of the first symptoms of which disease is the craving appetite, that seems as if it would never be satisfied. And there can be no doubt that, putting aside all the other circumstances that have been alluded to, there is much difference amongst individuals, in regard to the rapidity of the changes which their organism undergoes, and the amount of food required for its maintenance.

416. The influence of the supply of food upon the size of the individual, is very evident in the Vegetable kingdom; and it is most strikingly manifested, when a plant naturally growing in a poor dry soil is transferred to a damp rich one, or when we contrast two or more individuals of the same species, growing in localities of opposite characters. Thus, says Mr. Ward, "I have gathered, on the chalky borders of a wood in Kent, perfect specimens in full flower of *Erythræa Centaurium* (Common Centaury), not more than half an inch in height; consisting of one or two pairs of most minute leaves, with one solitary flower: these were growing on the bare chalk. By tracing the plant towards and in the wood, I found it gradually increasing in size, until its full development was attained in the open parts of the wood, where it became a glorious plant four or five feet in elevation, and covered with hundreds of flowers." On the other hand, by *starvation*, naturally or artificially induced, Plants may be dwarfed, or reduced in stature: thus the Dahlia has been diminished from six feet to two; the Spruce Fur from a lofty tree to a pigmy bush; and many of the trees of plains become more and more dwarfish as they ascend mountains, till at length they exist as mere underwood. Part

of this effect, however, is doubtless to be attributed to diminished temperature; which, as already remarked, concurs with deficiency of food in producing inferiority of size.

417. Variations in the supply of food would not appear to be effectual in producing a corresponding variety of size in the Animal kingdom: this is not, however, because Animals are in any degree less dependent than Plants upon a due supply of food; but because such a limitation of the supply, as would *dwarf* a Plant to any considerable extent, would be fatal to the life of an Animal. On the other hand, an excess of food, which (under favourable circumstances) would produce great increase in the size of the Plant, would have no corresponding influence on the Animal; for its size appears to be restrained within much narrower limits,—its period of growth being restricted to the early part of its life, and the dimensions proper to the species being rarely exceeded in any great degree. Even in the case of *giant* individuals, it does not appear that the excess of size is produced by an over-supply of food; but that the larger supply of food taken in is called for by the unusual wants of the system, —those wants being the result of an extraordinary activity in the processes of growth, and being traceable rather to the properties inherent in the system, than to any external agencies. Thus we not unfrequently hear of children, who have attained an extraordinary size at the age of a few years; and this excess of size is usually accompanied with other marks of precocious development. We shall hereafter see, that a provision exists in the Digestive apparatus, which absolutely prevents the reduction and preparation of the food, in any amount greatly surpassing that which the wants of the system demand (§ 474); and it is probably to this cause, in part, that we are to attribute the small degree of influence exerted by an excess of food, in producing an increased development of the Animal frame.

418. The influence of a diminished supply of food, in producing a marked inferiority in the size of Animals, is most effectually exerted during those early periods of growth, in which the condition of the system is most purely Vegetative. Thus it is well known to Entomologists, that, whilst it is rare to find Insects departing widely from the average size on the side of excess, dwarf-individuals, possessing only half the usual dimensions, or even less, are not uncommon; and there can be little doubt that these have suffered from a diminished supply of nutriment during their larva state. This variation is most apt to present itself in the very large species of Beetles, which pass several years in the larva state; and such dwarf-specimens have even been ranked as sub-species. Abstinence has been observed to produce the effect, upon some Caterpillars, of diminishing the number of moults and accelerating the transformation; in such cases, the Chrysalis is more delicate, and the size of the perfect Insect much below the average.

419. One of the most remarkable examples known, of the effect of food in modifying the development of Animals, is to be found in the

economy of the Hive-Bee. In every community, the majority of Individuals consists of *neuters;* which may be regarded as females, having the organs of the female sex undeveloped; and which, whilst incapable of reproduction, perform all the labours of the hive. The office of continuing the race is restricted to the *queen;* who is the only perfect female in the community. If by any accident the queen be destroyed, or if she be purposely removed for the sake of experiment, the bees choose two or three from amongst the *neuter eggs*, which have been deposited in their appropriate cells; and these they cause to be developed into *perfect queens*. The first operation is to change the cells in which they lie into *royal cells;* these differ considerably from the ordinary ones in form, and are of much larger dimensions. This is accomplished by breaking down the walls of the surrounding cells, removing the eggs or grubs they may contain, and rebuilding the central upon an enlarged scale, and upon the same plan as the royal cells in which the queens are ordinarily reared. When the eggs are hatched, the maggot is supplied with food of a very different nature from the farina or bee-bread (composed of a mixture of pollen and honey) which has been stored up for the nourishment of the workers: this food being of a jelly-like consistence and pungent, stimulating character. After the usual transformations, the grub becomes a perfect queen; differing from the neuter bee, into which it would otherwise have been changed, not only in the development of the reproductive system, but in the general form of the body, the proportionate shortness of the wings, the shape of the tongue, jaws, and sting, the absence of the hollows on the thighs in which the pollen is carried, and the loss of the power of secreting wax.

420. That insufficiency of wholesome food, continued through successive generations, may produce a marked effect, not merely upon the stature, but upon the form and condition of the body, even in the Human race, appears from many cases, in which such influence has operated on an extensive scale. Thus there are parts of Ireland inhabited by a population descended from those who were treated by the English as rebels two centuries since, and who were driven into mountainous tracts, bordering the sea, where they have been since exposed to the two great brutalizers of the human race, hunger and ignorance. The present race is distinguished physically from the kindred race of Meath and other neighbouring districts, where the same causes have not been in operation, by their low stature (not exceeding five feet two inches), their pot-bellies and bow-legs; whilst their open projecting mouths, with prominent teeth and exposed gums, their advancing cheek-bones and depressed noses, bear barbarism in their very front. "These spectres of a people that once were well-grown, able-bodied, and comely, stalk abroad into the daylight of civilization, the animal apparitions of Irish ugliness and Irish want."—The whole aboriginal population of New Holland presents a similar aspect; and apparently from the operation of the same causes.

421. When a larger quantity of food is habitually consumed than the wants of the system require, it is not converted into solid flesh; but it is got rid of by the various processes of excretion. The increased production of Muscular fibre depends, as we have already seen (§ 362), upon nothing so much as the exercise of the muscle. It cannot take place, unless the blood supply it with the materials: but no degree of richness of the blood can alone produce it. Consequently, the accumulation of nutritive matter in the blood is so far from being a condition of *health*, that it powerfully tends to produce *disease*,—either of an inflammatory character, if the fibrin predominate,—or of the hemorrhagic character, if the red corpuscles predominate. This state is most apt to present itself in those who live well and take little exercise; and the remedy for it is either to diminish the diet, or to increase the amount of exercise, so as to bring the two into harmony.

422. The continued over-supply of food has several injurious effects; it disorders the digestive processes, by stimulating them to undue activity, and lays the foundation for a complete derangement of them; it gives a predisposition to the various diseases of repletion, as already noticed; and it throws upon the excreting organs much more than their proper amount of labour, besides tending to produce a depraved condition of the matters to be drawn off by them, which renders the proper act of excretion still more difficult. When this is the case, various disorders arise, caused by the retention, within the circulating current, of substances which are very noxious to the general system, and which become most fertile sources of disease. What are commonly regarded as diseases of the biliary and urinary organs, are really, in a large proportion of cases, nothing else than disordered actions of these organs, occasioned by the irregular mode in which the products of decomposition are formed within the blood, and dependent upon some error in diet, either as regards quantity or quality. Thus the "lithic acid diathesis," in which there is an undue proportion of that substance in the urine, and of which Gout is a particular manifestation, is due, not to disorder of the kidney, but to an undue production of lithic acid in the blood; so long as the excreting action of the kidney is sufficient to prevent its accumulation in the blood, so long the general health is but little affected; but whenever that action receives a check, various constitutional symptoms indicate that the system is disturbed by the presence of this product of decomposition. And though our remedies may be rightly directed, in part, to facilitating its escape through the kidneys, yet the radical cure is to be sought only in the regulation of the diet, and in the prevention of the first production of the substance in question.—Similar remarks might probably be applied to disorders of the Liver; but we are, from various causes, far less perfectly acquainted with their character than we are with those of the Kidney.

423. There is only one tissue, the increase of which is directly produced by an over-supply of food. This is the Adipose or fatty. It is formed almost entirely at the expense of the non-azotized con-

stituents of the food; the walls of the cells, into which the fatty matter is secreted, being the only part of this tissue that is derived from the proteine-compounds of the blood. The production of the adipose tissue is most directly favoured by the presence of a large amount of fatty matter in the food; but it may also take place, as will be presently shown, by the conversion of starchy and saccharine substances into fatty compounds. It cannot occur, unless there be in the food a larger proportion of substances that can be thus appropriated, than is sufficient to maintain the heat of the system by the respiratory process. Consequently, whatever increases the demand for heat, is unfavourable to the deposition of fat; and *vice versâ*. The fattening of animals is now brought to a regular system; and experience has shown that rest and a warm temperature, with food containing a large amount of oily matter, are most conducive to the accumulation. Rest acts by keeping the respiration at a low standard; for it will hereafter be shown (Chap. VIII.), that a much larger proportion of carbonic acid is thrown off when the body is in active movement, than when it is in repose. External warmth has the same effect; the demand upon the calorifying power being diminished, and more of the combustible material being left, to be stored up as fat.

424. The deposition of fat affords a supply of combustible matter, against the time when it may be needed; and it is consequently found, that the duration of life in warm-blooded animals, when they are completely deprived of food, is in great degree proportional to the amount of fat they have previously accumulated. There is no sufficient reason to believe that fatty matter can be converted, within the animal body, into a proteine-compound, which can serve for the nutrition of the muscular and other tissues. But the greatest and most constant waste, when an animal is undergoing starvation, is that which is occasioned by the heat-producing process; this, so long as the supply lasts, is kept up by the store of fat, which is gradually consumed; and when it is completely exhausted, the temperature falls, hour by hour, until life can no longer be sustained, (§ 117). The use of this store of fat, in supplying any temporary deficiency in the food, becomes evident from such experiments; for when it has been completely exhausted, the withholding of a single meal proves fatal, from the want of power to sustain the calorifying process. We find that animals, which are likely to suffer from deficiency of food in the winter, or which spend that period in a state of quiescence, have a tendency to accumulate a store of fat in the autumn; which tendency seems principally to depend upon the nature of their food. We observe it chiefly in those Birds and Mammals which live upon seeds and grains; and these, when ripe, contain a large quantity of oily matter, which thus becomes a valuable store against the time of need. There are many birds, such as the beccafico so much esteemed in Italy, which are described, if killed at this season, as being "lumps of fat."

425. It is well known to breeders of cattle, that some varieties or breeds have a much greater tendency to the production of Adipose

tissue, than others placed under the same circumstances; and the former are therefore selected to undergo the fattening process. Corresponding differences may be met with among different individuals of the Human race; some persons having a remarkable tendency to the production of fat, under circumstances which do not seem by any means favourable to it, whilst others appear as much indisposed to this deposit. The latter condition we notice particularly in that temperament which is commonly termed the "bilious;" and it is important to bear in mind that, where such an indisposition exists, any superfluity of fatty matter in the food taken into the system, must be excreted again through the liver, instead of being retained and stored up in the body. It is very desirable, therefore, that such persons should abstain from any excess of this kind; since an habitual call upon the liver, to relieve the system of a superfluity of fatty matter, is certain to produce a disordered state of that organ; and in order to prevent it, the diet should be altered so as to include less of fatty matter, or the amount of exercise should be increased, so that it may be burned off by the additional respiration which then takes place.

426. We see, then, that the amount of food which can be properly appropriated by the system varies considerably in different individuals, and in the same individual under different circumstances. Consequently it is impossible to give any general rule, which shall apply to every one alike. The *average* quantity required by adult men, leading an active life, and exposed to the ordinary vicissitudes of temperature in our own climate, seems to be from 30 to 36 ounces of *dry* aliment. But a healthy condition may be kept up on scarcely more than half this allowance, if the muscular powers are but little exerted, and the surrounding temperature be high; provided that it consist of substances of a nutritious kind, united in proper proportions.

427. The value of different substances as aliment, depends in the first place upon the quantity of solid matter they contain; being of course the greater, as the solids form the larger proportion of the entire weight. Many esculent vegetables contain so large a quantity of water, that the nutriment they afford is very slight in proportion to their bulk.—Next it depends upon the proportion of digestible matter which the solid parts include; for it is not every substance containing the requisite ingredients, that is capable of being reduced to a state which enables it to be absorbed. Thus woody fibre is composed of the same elements as starch-gum; but it passes out of the intestinal canal unchanged, and therefore affords no nutriment. In the same manner, the horny tissues of animals, though nearly allied to proteine in their composition, are completely destitute of nutritive properties to Man and the higher animals, because not capable of being reduced by their digestive process; though certain insects appear capable of living exclusively upon them.

428. But when the watery and indigestible parts of the food are put out of consideration, and our attention is directed only to the soluble solids, we find a most important difference in the chemical

composition of different substances, which renders them more or less appropriate to the different purposes which have to be answered in the nutrition of the body. It has been already pointed out, that Vegetables possess the power of combining the *elements* furnished by the inorganic world into two classes of compounds,—the ternary, consisting of oxygen, hydrogen, and carbon,—and the quarternary, which consists of these elements, with the addition of azote or nitrogen. These two classes are hence termed the *non-azotized* and the *azotized*.

429. Now the azotized compounds which are formed by Plants, are essentially the same with those which are furnished by the flesh and by the albuminous fluids of Animals, as already shown (§ 169); and these are required for the reparation of the waste of the muscular tissue and for the general nutrition of the body. Consequently, unless the food contain a sufficient proportion of these substances, the body must be insufficiently nourished, and the strength must diminish, even though other elements of the food be in superabundance. The other azotized compounds existing in the animal body may be elaborated by the transformation of these proteine-compounds; so that when *they* are duly supplied, the system cannot become enfeebled for want of support.—But there is another azotized compound, Gelatin, that is furnished by Animals, to which nothing analogous exists in Plants; and this, although it cannot sustain life by itself, is a valuable adjunct to the proteine compounds. For as the gelatinous tissues suffer waste in common with the others, it is evident that if the gelatin be supplied already prepared, it may be at once applied to their nutrition; and thus the proportion of proteine, which they would otherwise require, is not demanded, and the labour of transformation is also saved. Further, there is this great advantage in combining a proportion of gelatin with the food,—especially when the digestive powers are feeble,—that being already in a state of perfect solution, it is taken up at once by the simple act of physical absorption or endormose, instead of requiring the selective absorption, which involves an act of cell-formation (§ 494). But there is no evidence that gelatin can ever be transformed into a proteine-compound, and can thus be applied to the nutrition of the muscular and other fibrous tissues; and the presumption, derived from the results of various experiments, is very strong the other way.

430. The quantity of azotized substances furnished by Plants is usually small in proportion to that of the non-azotized; being considerable only in the Corn-grains, and in the seeds of Leguminous plants, which the universal experience of ages has demonstrated to be the most nutritious of Vegetable substances. The non-azotized compounds exist under various forms; of which the principal are starch, sugar, and oil. The two former may be regarded as belonging to one class; because we know that starch and the substances allied to it may be converted into sugar by simple chemical processes, and that this transformation takes place readily both in the Vegetable and Animal economy. On the other hand, the oily matters contained in vegetable and

animal food, are usually ranked as a distinct group of alimentary substances; and it has been maintained that, under no circumstances, has the Animal the power of elaborating fatty matter from starchy or saccharine compounds. But this is now known to be an unfounded limitation; since the transformation of a saccharine into a fatty compound takes place in the case of bees, which form wax when fed upon pure sugar; and it has been recently shown that it may take place in the laboratory of the Chemist, butyric acid (the fatty acid of rancid butter) being one of the products of the fermentation of sugar taking place under peculiar circumstances.

431. The great use of these substances in the Animal economy, is to support the respiratory process, and thus maintain the temperature of the body. We have seen that, in the compounds of the *Saccharine* group (in which Starch is included) the amount of oxygen is no more than sufficient to form water with the hydrogen of the substance (§ 12); so that the carbon is free to combine with the oxygen taken in by the lungs, and thus becomes a source of calorifying power. Again, in the oily matters taken in as food, the proportion of oxygen is far smaller; so that they contain a large quantity of surplus hydrogen, as well as of carbon, ready to be burned off in the system, and thus to supply the heat required. This is obviously the ordinary destination of the alimentary matters belonging to these classes; and the greatest economy in the choice of diet is therefore exercised, when it is composed of azotized substances in sufficient amount to repair the waste of the system, and of non-azotized compounds which include free carbon and hydrogen in sufficient quantity to develop (with the aid of other processes) the requisite amount of heat by combination with oxygen. But if there be a deficiency in either of these kinds of aliment, the body must suffer. Should the supply of duly-prepared azotized matter be less than is required to repair the waste of the albuminous and gelatinous tissues, then these diminish in bulk and in vital power, though the heat of the body may be kept up to its proper standard. But if the non-azotized matter would be supplied in sufficient amount, or in a form in which it cannot be appropriated, the heat of the body cannot be sustained in any other way than by drawing upon the store of fat previously laid up.

432. Various circumstances lead to the belief, that the saccharine compounds are thus carried off by the respiratory process, within a short time after they have been introduced into the system. They have not been detected in the chyle drawn from the lacteal absorbents; but there seems reason to believe that, in consequence of their ready solubility, they are directly taken up by the blood (§ 493), and that they are so rapidly burned off there, as to escape notice in that fluid. But it has been lately shown by Dr. Buchanan, that, if the blood be examined within a short time after a meal consisting in part of farinaceous and saccharine substances, a very appreciable quantity of saccharine matter is found in it. This soon disappears, however; being eliminated or separated from the blood by the action of the

lungs. In fact it is very probable, that a large proportion of the matter thus taken in never enters the general circulation at all; as the blood of the mesenteric veins proceeds to the lungs, after passing through the liver, before it is transmitted to the systemic arteries, and may there lose its saccharine matter, as fast as this is taken in from the stomach. After a meal containing the ordinary admixture of saccharine, oily, and albuminous compounds, it is probable that the saccharine are first received into the blood, and are the first to be eliminated from it; and that, by the time *they* have been all consumed, the oily matter, introduced through the more circuitous channel of the lacteal system, is ready to answer the same purpose. If these are exhausted before a fresh supply of food is taken in, cold as well as hunger is experienced; and the body is in this condition peculiarly liable to suffer from any depressing causes, such as a low external temperature, poisonous miasmata, &c.; hence the prudence of avoiding exposure to such influences upon an empty stomach.

433. We can thus in part account for the fact, which universal experience has established, that in warm-blooded animals, a mixture of azotized and non-azotized substances is the diet most conducive to the welfare of the body; and that, in all but the purely carnivorous tribes, the diet provided by Nature consists not only of albuminous, gelatinous, and oily substances, such as are furnished by the flesh and fat of animals, but also of saccharine or farinaceous matter. This is the diet to which Man is evidently best adapted; and it is remarkable how completely accordant is his use of the ordinary materials of food, with the principles now established by chemical and physiological research, in regard to the wants of his bodily system, and the best mode of supplying them. Thus, good wheaten bread contains, more nearly than any other substance in ordinary use, that proportion of azotized and non-azotized matter, which is adapted to repair the waste of the system, and to supply the necessary amount of combustible material, under the ordinary conditions of civilized life in temperate climates; and we find that the health and strength can be more perfectly sustained upon that substance, than upon any other taken alone. The addition of a moderate quantity of butter increases its heat-producing powers; and this is especially useful when the temperature is low,—under which condition, there is usually an increased disposition to the employment of fatty matters as articles of food. On the other hand, if the body be subject to violent exertion, advantage is gained by increasing the proportion of the proteine-compounds, by the addition of animal flesh; and, under any circumstances, there is an economy in the use of gelatin, in the form of soup, which diminishes the demand for other azotized matter. The use of animal flesh, however, as a principal article of diet, except when the individual is leading the incessantly-active life of a carnivorous animal, is very far from being economical, and is positively injurious to the welfare of the body.

434. On the other hand, in rice, potatoes, casava-meal, and simi-

lar substances, the farinaceous or saccharine components form so very large a proportion of the whole mass, and the proteine-compounds are present in so very small an amount, that they are insufficient to support the bodily vigour when taken alone, unless a larger quantity be ingested, so as to supply the requisite proportion of azotized matter. But when these substances form part of a mixed diet, the other ingredient of which consists of animal flesh, a much smaller quantity of them suffices; and the same kind of combination is then formed, as exists in the single article of bread. Those in whose diet the farinaceous elements predominate largely, and the azotized compounds exist in the smallest amount compatible with the maintenance of the bodily vigour, are exempt from many diseases incident to those who live more highly; thus among the potato-eating Irish, and the oatmeal-feeding Scotch, gout is a disease never heard of; whilst among the richer classes of the same countries, there is no peculiar exemption from it.

435. The oily constituents of food are most abundant in the diet of the inhabitants of frigid zones, who feed upon whales, seals, and other animals loaded with fat, and who devour this fat with avidity, as if instinctively guided to its use. It is by the enormous quantity of this substance taken in by them, that they are enabled to pass a large part of the year in a temperature below that of our coldest winter, spending a great portion of their time in the open air; as well as to sustain the extreme of cold, to which they are occasionally subjected. And in consequence of its being more slowly introduced into the system than most other substances, a larger quantity may be taken in at one time, without palling the appetite; whilst its bland and non-irritating character favours its being retained until it is all absorbed. In this manner, the Esquimaux and Greenlanders are enabled to take in 20 or 30 pounds of blubber at a meal; and, when thus supplied, to pass several days without food.—On the other hand, among the inhabitants of warm climates there is comparatively little disposition to the use of oily matter as food; and the quantity of it contained in most articles of their diet is comparatively small.

436. In the Milk, which is the sole nutriment of young Mammalia during the period immediately succeeding their birth, we find an admixture of albuminous, saccharine, and oleaginous substances; which indicates the intention of the Creator, that all these should be employed as components of the ordinary diet. The Casein or cheesy matter is a proteine-compound; the Butyrine of butter is but a slight modification of its ordinary fats; and its sugar differs from that in common use, only by its larger proportion of water. The relative amount of these ingredients in the milk of different animals is subject, as we shall hereafter see, to considerable variation; but they constantly exist, at least in the milk of the Herbivorous Mammalia, and of those which, like Man, subsist upon a mixed diet. But it has been recently asserted, that the milk of the purely Carnivorous animals is

destitute of Sugar, consisting, like their food, of proteine-compounds and fatty matter only.

437. No fact in Dietetics is better established than the impossibility of long sustaining health, or even life, upon any single alimentary principle. Neither pure albumen nor fibrin, gelatin nor gum, sugar nor starch, oil nor fat, taken alone for any length of time, can serve for the due nutrition of the body. This is partly due, so far as the non-azotized compounds are concerned, to their incapability of supplying the waste of the albuminous tissues. This reason does not apply, however, to the proteine-compounds; which can serve not only for the reparation of the body, but can also afford the carbon and hydrogen requisite for the sustenance of its temperature. The real cause is to be found in the fact, that the continued use of *single* alimentary substances excites such a feeling of disgust, that the animals experimented on seem at last to prefer starvation, rather than the ingestion of them. Consequently it is quite impossible to ascertain, by such experiments, the nutritive power of the different alimentary principles; no animal being capable of sustaining life upon less than two of them at least. The same disgust is experienced by Man, when too long confined to any article of diet, which is very simple in its composition; and a craving for change is then experienced, which the strongest will is scarcely able to resist. Thus, in the treatment of Diabetes, a disease in which there is an undue tendency to the production of sugar in the system, it is very important to abstain completely from the introduction of saccharine or farinaceous matters in the food; but the craving for vegetable food, which is experienced when the diet has long consisted of meat alone, is such as to make perseverance in the latter very difficult; and a means has been latterly devised of supplying this want without injury, by the use of bread from which the starchy portion has been removed, the gluten or azotized matter alone being eaten.*

438. The organic compounds, which have been enumerated as supplying the various wants of the system, would be totally useless without the admixture of certain inorganic substances, which also form a constituent part of the bodily frame, and which are constantly being voided by the excretions, especially in the Urine. These substances have various uses in the system. Thus common *Salt*, or the Chloride of Sodium, appears to afford, by its decomposition, the muriatic acid which is concerned in the digestive process, and the soda

* As an illustration of the advantage of this treatment, even in unpromising cases, the Author may cite an instance which has come under his own observation. The patient was a man 72 years of age; the disease had lasted at least a year, and was decidedly on the increase; considerable loss of flesh and of muscular vigour had taken place; and the quantity of sugar in the urine was such as to make it quite sweet to the taste. By the careful restriction of his diet to animal flesh and gluten-bread, this individual has kept the disease in complete check for more than 15 months; he has gained flesh, and improved in strength; and his urine is no longer sweet. Having two or three times ventured upon a return to his ordinary diet, his old symptoms have immediately manifested themselves, warning him of the necessity of perseverance in the strict regimen prescribed for him.

which is an important constituent of the bile. Its presence in the serum of the blood, also, and in the various animal fluids which are derived from this, probably aids in preventing the decomposition of the organic constituents of these fluids,—*Phosphorus* has been supposed, until recently, to be chiefly requisite as one of the materials of the nervous tissue (§ 383); and also, when acidified by oxygen, to unite with lime in forming the bone-earth by which bone is consolidated. But there is reason to believe, from the results of late inquiries, that the acid and alkaline phosphate of lime and soda are very important constituents of the various fluid secretions, and have a large share in their respective actions. It has even been maintained that the acid phosphate of lime is the essential ingredient in the gastric juice, by which the first solutions of the food are effected.—*Sulphur* exists in small quantities in several animal tissues; but its part appears to be by no means so important as that performed by Phosphorus.—*Lime* is required for the consolidation of the bones, and for the production of the shells and other hard parts that form the skeletons of the Invertebrata; and also as the base of the acid phosphate, which has been just referred to as an important constituent of the animal fluids.—Lastly, *Iron* is an essential constituent of Hæmatosine; and is consequently required for the production of the red corpuscles of the blood in Vertebrated animals.

439. These substances are contained, more or less abundantly, in most of the articles generally used as food; and where they are deficient, the animal suffers in consequence, if they be not supplied in any other way.—Thus, common Salt exists, in no inconsiderable amount, in the flesh and fluids of animals, in the milk, and in the substance of the egg; it is not so abundant, however, in Plants; and the deficiency is usually supplied to herbivorous animals in some other way. Thus, salt is purposely mingled with the food of domesticated animals; and in most parts of the world inhabited by wild cattle, there are spots where it exists in the soil, and to which they resort to obtain it. Such are the "buffalo-licks" of North America.—*Phosphorus* exists also, in combination with proteine-compounds, in all animal substances composed of these; and in the state of phosphate, combined with lime, magnesia, and soda, it exists largely in many vegetable substances ordinarily used as food. The phosphate of lime is particularly abundant in the seeds of the grasses; and it also exists largely, in combination with casein, in Milk.—*Sulphur* is also derived alike from vegetable and animal substances. It exists, in union with proteine-compounds, in flesh, eggs, and milk; also in several vegetable substances; and, in the form of sulphate of lime, in most of the river and spring water that we drink.

440. *Lime* is one of the most universally diffused of all mineral bodies; for there are very few Animal or Vegetable substances in which it does not exist. The principal forms in which it is an element of Animal nutrition, are the carbonate and phosphate. Both these are found in the ashes of the grasses, and of other plants used as food;

the phosphate of lime being particularly abundant (as already mentioned) in the corn-grains. The production of these cannot take place, to their fullest extent, unless the soil previously contain phosphate of lime in a state in which the plant can receive it; and it is now understood, that the diminished fertility of many lands is due, in great part, to the exhaustion of the soil as regards this ingredient. The restoration of the alkaline and earthy phosphates to the soil, in the form of manure, is the obvious means of preserving its fertility; but so long as a very large proportion of the excrements of animals (the materials of which are originally derived from the earth, through the vegetables it supplies), is allowed to run to waste, so long will it be necessary that the requisite amount of phosphate of lime should be drawn from foreign sources.

441. The phosphate of lime, as already mentioned, seems to perform important offices of a chemical nature in the animal economy, besides being the chief solidifying ingredient of bones and teeth; but the carbonate would seem principally destined to mechanical uses only; and we find it predominating, or existing as the sole mineral ingredient, in those non-vascular tissues of the Invertebrated animals, which give support and protection to their soft parts (§ 289). The degree of development of these tissues depends in great part upon the supply of carbonate of lime which the animals receive. Thus, the Mollusca which inhabit the sea, find in its waters the proportion of that substance which they require; but those which dwell in streams and fresh water lakes, that contain but a small quantity of lime, form very thin shells; whilst the very same species inhabiting lakes, which, from peculiar local causes, contain a large impregnation of calcareous matter, form shells of remarkable thickness.—The Crustacea, which periodically throw off their calcareous envelop (§ 297), are enabled to renew it with rapidity by a very curious provision. There is laid up in the walls of their stomachs a considerable supply of calcareous matter, in the form of little concretions, which are commonly known as "crabs' eyes." When the shell is thrown off, this matter is taken up by the circulating current, and is thrown out from the surface, mingled with the animal matter of which the shell is composed. This hardens in a day or two, and the new covering is complete. The concretions in the stomach are then found to have disappeared; but they are gradually replaced, before the supply of lime they contain is again drawn upon. The large amount of carbonate of lime which is required by the laying Hen, is derived from chalk, mortar, or other substances containing it, which she is compelled by her instinct to eat; and if the supply of these be withheld, the eggs which she deposits are soft on their exterior,—not being destitute of shell, as commonly supposed,—but having the fibrous element of the shell (§ 181) unconsolidated by the intervening deposit of chalky particles.

2. *Of the Digestive Apparatus, and its Actions in general.*

442. It has been already pointed out, that the nature of the food of Animals is so far different from that of Plants, as to require the preparatory process of Digestion, before its nutritious parts can be taken up by the absorbent vessels and received into the system. This process may be said to have three different purposes in view:—the reduction of the alimentary matter to a fluid form, so that it may become capable of absorption; the separation of that portion of it which is fit to be assimilated or converted into organized texture, from that which cannot serve this purpose, and which is at once rejected;—and the alteration, to a certain extent when required, of the chemical constitution of the former, which prepares it for the important changes it is subsequently to undergo. The simplest conditions requisite for the accomplishment of these purposes are the following:—a fluid capable of performing the solution, and of effecting the required chemical changes;—a fluid capable of separating the excrementitious matter, by a process analogous to chemical precipitation;—and a cavity or sac in which these operations may be performed.

443. In the lowest Animals, we find this cavity formed upon a very simple plan; the digestive sac being a mere excavation in the solid tissue of the body, lined with a membrane which is an inverted continuation of the external integument, and communicating with the exterior by one orifice only, through which food is drawn in, and excrementitious matter rejected. In the little Hydra, or fresh-water Polype, the external covering of the body and the lining of the stomach correspond so closely in their structure,—their actions differing only with their situation,—as to be mutually convertible; for the animal may be turned completely inside-out, without its functions being deranged. The fluid necessary to dissolve the food, known by the name of "gastric fluid," or "gastric juice," is secreted in the walls of the stomach; and, from the transparency of the tissues, the whole process may be watched. The prey is frequently, and indeed generally introduced alive, by the contractile power of the arms, which coil round it, and gradually draw it into the mouth or entrance to the stomach; and its movements may often be observed to continue for some time after it has been swallowed. In a little time, however, its outline appears less distinct, and a turbid film partly conceals it; the soft parts are soon dissolved and reduced to a fluid state; and any firm indigestible portions which the body may contain, are rejected through the aperture by which it entered. The nutritive matter is absorbed by the walls of the stomach, every part of which appears to be endowed with equal power in this respect; and it is conveyed to the remoter parts of the arms by the simple imbibition of one part from another, without any proper circulation through vessels.

444. In Polypes of a higher conformation, however, the digestive cavity is provided with a second orifice; from the dilated cavity or

stomach, an intestinal tube proceeds; and this has a termination distinct from the mouth, though often in its neighbourhood. The food, before entering the stomach, is submitted to a powerful triturating apparatus, resembling the gizzard of birds, by which it is broken down; and in the digestive cavity it is submitted, not merely to the action of the gastric fluid, but also to that of the bile, which is secreted in little follicles in the walls of the stomach, and which is poured into its cavity during the process of digestion,—being easily recognized by its bright yellow colour. The excrementitious matter is rejected in the form of little pellets, through the intestinal tube.

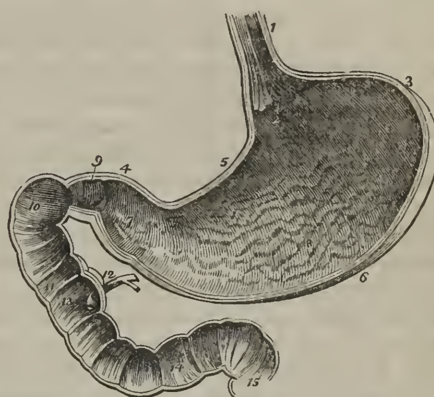
445. As we ascend the Animal scale, we find the digestive apparatus gradually increased in complexity; but its essential characters remain the same. Near the entrance to the stomach, we usually find an apparatus for effecting the mechanical reduction of the food, by which its subsequent solution may be rendered more easy. This may consist of a set of teeth; either fixed in the mouth, as in Mammalia and Reptiles; or more particularly besetting the pharynx, as in Fishes; or attached to the walls of the stomach, as in Crustacea. Or it may be formed by the tongue, converted into a sort of rasp; as in the common Limpet, which thus reduces the sea-weeds that constitute its chief food. Or the same purpose may be answered by a gizzard, or first stomach, with dense muscular and tendinous walls; such as we find in the grain-eating Birds, and many Insects, and in certain Mollusks and Polypes. But where the food is already composed of very minute particles, or is received in a liquid state, (as in the case of those animals which live upon the juices of others,) or is easily acted on by the gastric juice, no such preparation is requisite.

446. Before the food reaches the true digestive stomach, it is sometimes delayed in a previous cavity, in order that it may be macerated in fluid, and may be thoroughly saturated with it. This is the purpose of the *crop* of Birds, and of the first stomach of Ruminant animals. When this incorporation with fluid is not effected before the food is subjected to the triturating process, it usually takes place concurrently with it; and in those animals which reduce their food in the mouth by the process of mastication, there is a special secretion of fluid into that cavity for this purpose; this fluid is termed Saliva, and the act by which it is incorporated with the food is termed *insalivation.* The mechanical reduction of the aliment, and its incorporation with fluid, constitute, as we shall hereafter see, a very important preparation for the *true digestive* process.

447. This process, among higher animals, takes place exclusively, or nearly so, in the *stomach;* the form of which varies with the character of the food. When this is of a nature to be easily acted on by the gastric fluid, the stomach is a simple enlargement of the alimentary canal, almost in the direct line between the œsophagus and the intestinal tube; so that there is little provision for the delay of the food in its cavity. But when the aliment is such as to be less easily reduced, and requires to be submitted to the action of the gastric fluid, for a longer period, the stomach forms a more considerable

enlargement, and is placed more out of the direct line between the œsophagus and the commencement of the intestine. The former condition obtains in the Carnivora, and particularly in those which live more upon blood than upon flesh,—such as Weasels, Stoats, &c., in which this part of the alimentary tube is almost straight; the latter condition is found among the Herbivora, and the provision for the delay of the aliment attains its greatest complexity in the Ruminant animals. The form of the Human stomach (Fig. 70) is intermediate between that of purely carnivorous and purely herbivorous animals. As in the former, there is a direct passage from the cardiac orifice or entrance of the œsophagus, to the pyloric orifice or commencement of the intestine; but there is also a considerable dilatation or *cul de sac*, which is out of that line; and it appears that, during the digestive process, there is a constriction across the stomach, which separates the cardiac portion from the pyloric, and causes the retention of the food in the dilated part or large extremity. The gastric fluid is still secreted in the walls of this organ, by scattered follicles which pour their products into its cavity through separate orifices; but the bile is elaborated by a distinct organ, altogether removed from it, which transmits its secretion by a single duct, that opens into the intestinal tube at a short distance from its commencement.

Fig. 70.



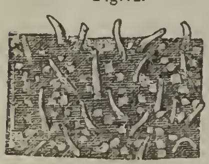
A vertical and longitudinal section of the Human stomach and duodenum, made in such a direction as to include the two orifices of the stomach. 1. The œsophagus; upon its internal surface the plicated arrangement of the cuticular epithelium is shown. 2. The cardiac orifice of the stomach, around which the fringed border of the cuticular epithelium is seen. 3. The great end of the stomach. 4. Its lesser or pyloric end. 5. The lesser curve. 6. The greater curve. 7. The dilatation at the lesser end of the stomach. which has received from Willis the name of antrum of the pylorus. This may be regarded as the rudiment of a second stomach. 8. The rugæ of the stomach formed by the mucous membrane: their longitudinal direction is shown. 9. The pylorus. 10. The oblique portion of the duodenum. 11. The descending portion. 12. The pancreatic duct and the ductus communis choledochus close to their termination. 13. The papilla upon which the ducts open. 14. The transverse portion of the duodenum. 15. The commencement of the jejunum. In the interior of the duodenum and jejunum, the valvulæ conniventes are seen.

448. The action of the Stomach is restricted, in the higher animals, to the *reduction* of the food by the solvent powers of the gastric juice, and to the *absorption* (by the vessels in its walls) of those parts of it which are in a state of the most perfect solution. The change which is produced by the admixture of the bile, takes place in the intestine; and the principal part of the nutritive elements of the food are taken up by the absorbent vessels of the walls of the intestine, after that process has been accomplished. It would seem as if the preparation

of the food for absorption were not by any means completed, in this first portion of the alimentary canal; for it is still destined to pass through a long and convoluted tube, which is sometimes extended to an extraordinary degree; and in this passage it is gradually exhausted of its nutritious matter. The length of the intestinal canal bears a close relation to the character of the food. In the Carnivorous animals, whose aliment is easily dissolved and prepared for conversion into blood, the intestine is comparatively short; thus in the Lion and other Felines it is no more than three times the length of the body; and in some of the blood-sucking Bats, it is almost straight and simple. On the other hand, in Herbivorous animals it is of enormous length; thus in the Sheep it is about twenty-eight times as long as the body. In animals whose diet is mixed, its length is intermediate between these extremes; thus in Man, the whole length of the intestinal tube is about thirty feet, or between five and six times that of the body.—The intestine is of much smaller diameter along its first portion, than it is nearer its termination; and it is consequently distinguished into the *small* and the *large*. In the small intestine, which constitutes in Man about five-sixths of the whole, the surface of the mucous membrane is greatly extended by the *valvulæ conniventes*, which are folds or duplicatures, often several lines in breadth, not entirely surrounding the intestine, but extending for about one-half, or three-fourths of its circumference. These are wanting at the lower part of the ileum. The whole surface of the mucous membrane of the small intestine, below the entrance of the biliary ducts, is thickly covered with *villi*, or little root-like projections, in which the proper absorbent vessels originate. No proper valvulæ conniventes exist in the large intestine; the only extensions of the mucous membrane being crescentic folds at the edges of the sacculi or pouch-like dilatations in its walls; and the villi are comparatively few in number, gradually disappearing towards the termination of the intestine.

449. The mucous membrane of the alimentary canal, through its whole course, is studded with the orifices of numerous scattered glands, which lie in its thickness, or immediately beneath it. The simplest of these are the follicles of Lieberkühn, which are small pouches, formed by an inflexion of the mucous surface, analogous to the follicles of other mucous membranes, and apparently destined for the elaboration of the protective secretion (§ 237, see Figs. 27 and 28). These follicles, in the small intestine, are very simple in their character, and not very deep; and their apertures, which are small, are situated for the most part around the bases of the villi. In the large intestine they are more prolonged, especially towards the extremity of the rectum, where they form a distinct layer, the component tubes of which are visible to the naked eye; they probably form the peculiarly thick and tenacious mucus of that part. These mucous follicles

Fig. 71.



Mucous coat of small intestines as altered in fever; the follicles of Lieberkühn filled with tenacious white secretion.

become particularly evident when the membrane is inflamed; for they then secrete an opaque whitish matter, which is absent in the healthy state, and which distinguishes their orifices (Fig. 71).—A modified kind of these follicles, rather more complex in structure, is found abundantly in the stomach; where it is concerned in the secretion of the gastric fluid (§ 469).

450. The coats of the intestine contain other glandulæ, which appear destined, not so much to elaborate fluids of use in the system, as to draw off from the blood certain products of decomposition, which are to be excreted from it. These are commonly known as the glands of Brunner, and of Peyer, after the names of their respective discoverers.—The glands of Brunner are situated in the duodenum, and lie, not in the mucous but in the sub-mucous tissue. Though their size is only about that of a hemp-seed, they are of very complex structure, consisting of several hundred follicles, clustered round the ramifications of an excretory duct, so as to resemble the Salivary glands; and each pours its secretion through a single orifice into the intestinal tube. The glands of Peyer are either *solitary* or *agminated;* the latter form large patches, which are made up of aggregations of the former. Each solitary gland consists of a closed spheroidal vesicle, which is half imbedded in the mucous membrane, but which also forms an elevated projection above it; and this projection is surrounded by a ring or zone of openings, which lead into an annular cluster of Lieberkühnian follicles. On rupturing one of the Peyerian vesicles, its cavity is found to contain a grayish-white matter, interspersed with cells in various stages of development. The complete *closure* of this cavity would seem to render it an exception to all general rules of glandular structure; but this is not so in reality; for it will be shown hereafter that many other glandular follicles in an early stage of their development are equally closed (Chap. IX.); and it appears that the Peyerian vesicles, when mature, discharge their contents by an opening which then forms in the most projecting portion of their walls,—these contents passing at once into the cavity of the intestine, instead of being poured (as in other cases) into an excretory duct.—Of the nature of the secretions of these intestinal glandulæ, nothing has been positively ascertained; but some probable inferences from well-known facts will be stated hereafter (Chap. XI).

3. *Movements of the Alimentary Canal.*

451. The food which is conveyed to the mouth, is grasped with the lips, by a muscular effort, which is voluntary in the adult under ordinary circumstances, but which may be performed instinctively when the influence of the will is withdrawn; in the infant, as among the lower animals, the action seems purely instinctive, the nipple of the mother being firmly grasped by the lips when introduced between them, even after the brain has been removed.—By the act of mastication, which then succeeds, the food is triturated and mingled with

the salivary secretion; and is thus prepared for the further process of solution, to which it is to be subjected in the stomach. The degree of this preparation, and the form of the instruments by which it is effected, vary in different animals, according to the nature of the food. In those Carnivora, whose aliment consists exclusively of flesh, very little mastication is necessary, because this substance is very readily acted on by the gastric fluid; and we accordingly find the molar teeth raised into sharp cutting edges, and working against each other with a scissors-like action (the only one permitted by the articulation of the jaw), so as simply to divide the food. On the other hand, in those Herbivora, whose food consists of tough vegetable substances, such as the leaves of grasses, or the stems and roots of other plants, we find the molar or grinding teeth peculiarly adapted to its reduction; their surface being extended horizontally, and being kept continually rough, by the alternation of vertical plates of different degrees of hardness; and the lower jaw being so connected with the skull, that great freedom of motion is permitted. In Man we find an intermediate conformation, as regards both the teeth and the articulation of the jaw; for the molar teeth possess broad surfaces, which are covered with a continuous coat of enamel, but which are raised into rounded tubercles; and the articulation of the jaw allows it a degree of freedom, which is much greater than that possessed by the Carnivora; although inferior to that which exist in many Herbivora. The whole apparatus of Mastication is so formed in Man, as to lead to the conclusion that he is destined to live on a mixed diet, composed in part of animal flesh, and in part of vegetable substances that are sufficiently soft to be reduced by the simple act of crushing, or by the slight trituration for which the molar teeth are adapted.

452. The mechanical reduction of the food by Mastication, and the incorporation of the Salivary secretion with its substance, constitute a very important step in the Digestive process. We shall hereafter see that the operations, to which the alimentary matter is subjected in the stomach, are of a purely Chemical nature; and this preparation is exactly of the same character as that which the Chemist finds it advantageous to make, when he is operating on a substance of difficult solution. For nothing is so favourable to the action of the solvent, as the previous reduction of the matter to be dissolved, and its thorough incorporation with the fluid that is to act upon it. We shall hereafter see, that the relative properties of the Saliva and of the Gastric fluid are such, that, by the minute admixture of the food with the former, the latter finds access to every particle of it. Hence the practice of eating so rapidly, that Mastication and Insalivation are insufficiently performed, is extremely injurious; since it throws more work upon the Stomach than it ought to perform, by rendering its solvent action more difficult. There can be no doubt that, by the prolonged continuance of it, a foundation is laid for the distressing complaint termed Dyspepsia, or difficulty of digestion; and where any form of this complaint exists, too much attention cannot be paid to the efficient reduction of the food in the mouth.

453. When the aliment has been sufficiently triturated, it is conveyed into the Pharynx by the act of *Deglutition* or swallowing. This act involves a great many distinct movements, into a minute description of which we shall not here enter; but it is desirable that its general nature should be well understood. It is one of those most purely *reflex* in its character (§ 394), and is not capable of being performed or even controlled by a voluntary effort. This statement may seem inconsistent with the fact, that we swallow when we will; but it is not so in reality. The muscular movements which are concerned in deglutition, are excited by nerves that proceed from the spinal cord, not from the brain; these motor nerves are excited to action, by the contact of solid or fluid matters with the mucous surface of the fauces, —and in no other way. The impression produced by the contact is conveyed to the *medulla oblongata*, or that portion of the spinal cord which lies within the cranium, by afferent nerves that terminate in it; and, in immediate respondence to that impression, a motor impulse is transmitted from it, which calls the muscles into the combined action necessary to produce the movement. Now this contact *also* produces a sensation, provided the brain be sound and awake, because nervous fibres proceed from the mucous surface to the brain as well as to the spinal cord; but this sensation is not a necessary link in the chain of actions, by which the movement is produced; for the act of Deglutition takes place during profound sleep, when all sensation is suspended, and it may be excited even after the brain has been removed. It *seems* to be voluntary, under ordinary circumstances, simply because it is by an act of the will, that the matter to be swallowed is carried backwards into contact with the fauces; but that it is not so in reality, is shown by the fact, that when this impression has once been made with sufficient force, we cannot by any effort of the will, prevent the action. We have a good example of this in the following circumstance, of no very unfrequent occurrence. The tickling of the upper part of the fauces with a feather is often practised to induce vomiting; but if the end of the feather be carried too far down, it excites the act of deglutition instead; the feather is grasped by the pharynx and drawn downwards; and if it be not held tenaciously between the fingers, it is drawn from them and carried downwards into the stomach.

454. The carrying-back of the alimentary matter, so that it reaches the fauces or upper part of the pharynx, is principally accomplished by the tongue; when it has passed the anterior palatine arches, these contract and close over the tongue, so as to prevent the return of the food into the mouth; and at the same time the posterior palatine arches and the uvula are so drawn together, as to prevent its passage into the posterior nares. The larynx is drawn forwards beneath the root of the tongue, and the epiglottis is pressed down over the rima glottidis, so that nothing can enter the latter, unless drawn towards it by an act of inspiration. When fairly within the pharynx, the alimentary matter is seized by the constrictors which enclose that part of the ali-

mentary tube, and is drawn downwards by them into the œsophagus, which is the cylindrical continuation of it. The continued action of the constrictors serves to propel the food along the œsophagus; their movement being of a reflex nature, excited by the contact of the substance contained in the tube, with its lining membrane,—which produces an impression that is transmitted to the medulla oblongata, and is reflected back as a motor impulse to the muscles. We have here a distinct case of reflex action without sensation; for we have no consciousness of the ordinary passage of food down the œsophagus, unless it occasion pressure on the surrounding parts through its bulk, or unduly irritate the lining membrane by its high or low temperature or its acrid qualities; and yet it may be shown by experiment, that the completeness of the nervous circle is requisite for the excitement of the movement, which will not take place when it is interrupted either by division of the nerves, or by destruction or paralysis of the medulla oblongata.

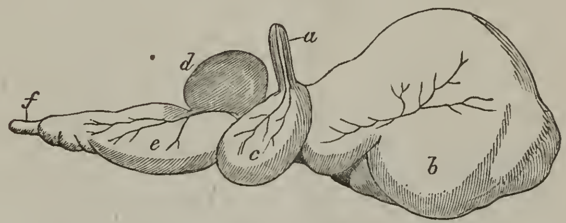
455. The progress of the food along the Œsophagus is aided by the action of the muscular coat peculiar to it. This is composed of the non-striated fibre; and, like that of the intestinal canal further on, it is usually stimulated to contraction by the *direct contact* of the stimulus, and not either by the will, or by the reflex action of the spinal cord. The movement produced by it is of the *peristaltic* or wave-like kind; the contractions being limited to one portion of the tube, and being propagated along it from above downwards. This action continues after the division of all the nerves supplying the œsophagus; and it cannot, therefore, be dependent upon the brain or spinal cord. It may be observed to take place in a rhythmical manner (that is, at short and tolerably regular intervals), whilst a meal is being swallowed; but as the stomach becomes full, the intervals are longer and the wave-like contractions less frequent. The degree in which the action of the œsophagus alone, without that of the surrounding muscles, is capable of propelling the food into the stomach, seems to vary in different animals. When the latter are paralyzed in the Dog, by section of the nerves that supply them, the food that has entered the œsophagus is still propelled into the stomach; but this is not the case in the Rabbit, the action of its œsophageal fibres not being sufficient to carry the food onwards to the stomach, though it will expel it from the divided extremity of the tube when it is cut across. The usual peristaltic movements of the œosophagus are reversed in Vomiting; and this reversion has been observed, even after the separation of the stomach from the œsophagus, as a consequence of the injection of tartar emetic into the veins.

456. At the point where the œsophagus enters the Stomach,—the cardiac orifice of the latter,—there is a sort of sphincter, or circular muscle, which is usually closed. This opens when there is a sufficient pressure on it, made by the accumulated food propelled by the movements of the œsophagus above; and it then closes again, so as to retain the food in the stomach. The closure is due to reflex ac-

tion; for when the nerves supplying it are divided, the sphincter no longer contracts, and the food regurgitates into the œsophagus. The opening of the cardiac is one of the first acts which takes place in vomiting.

457. In Ruminating animals, there is a very remarkable conformation at the lower end of the œsophagus, which is destined to regulate the passage of food into the different compartments of the stomach, according as it has been submitted to the second mastication, or not. The œsophagus does not terminate at its opening into the first stomach or paunch, but it is continued onwards as a deep groove with two lips (Fig. 73): by the closure of these lips it is made to form a tube, which serves to convey the food onwards into the third stomach; but when they separate, the food is allowed to pass either into the first or the second stomachs. When the food is first swallowed, it undergoes but very little mastication; it is consequently firm in its consistence, and is brought down to the termination of the œsophagus in dry bulky masses. These separate the lips of the groove or demi-canal, and pass into the first and second stomachs. After they have been macerated in the fluids of these cavities, they are returned to the mouth by a

Fig. 72.



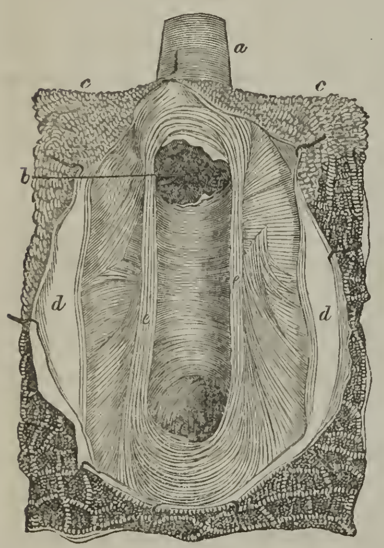
Stomach of Sheep;—*a*, œsophagus; *b*, paunch; *c*, second, or honeycomb stomach; *d*, third stomach, or many-plies; *e*, fourth stomach or reed; *f*, pylorus.

reverse peristaltic action of the œsophagus; this return takes place in a very regular manner, the food being shaped into globular pellets by compression within a sort of mould formed by the demi-canal, and these pellets being conveyed to the mouth at regular intervals, apparently by a rhythmical movement of the œsophagus. It is then subjected to a prolonged mastication within the mouth (the "chewing of the cud"), by which it is thoroughly triturated and impregnated with saliva; after which it is again swallowed in a pulpy semi-fluid state. It now passes along the groove which forms the continuation of the œsophagus, without opening its lips; and is thus conveyed into the third stomach, whence it passes to the fourth, in which alone the true digestive process takes place. Now, that the condition of the food as to bulk and solidity, is the circumstance which determines the opening or closure of the lips of the groove, and which consequently occasions its passage into the first and second stomachs, or into the third and fourth, appears from the experiments of Flourens; who found that when the food, the first time of being swallowed, was arti-

ficially reduced to a soft and pulpy condition, it passed for the most part along the demi-canal into the third stomach, as if it had been ruminated,—only a small portion finding its way into the first and second stomachs. How far the actions of this curious apparatus are dependent upon nervous influence,—or how far they are due to the exercise of the contractility of the muscular fibre, directly excited by the contact of the substances with the lining membrane of the tubes and cavities,—has not yet been clearly ascertained.

458. The food, when introduced into the Stomach, and submitted to the solvent action of its secretions, is also subjected to a peculiar movement, which is effected by the muscular walls of that organ. The purpose of this motion is obviously to keep the contents of the stomach in that state of constant agitation, which is most favourable to their chemical solution; and particularly to bring every portion of the alimentary matter into contact with the walls of the stomach, so as to be subjected to the action of the fluid, which is poured forth from them during the digestive process. The movement is produced by the alternate shortening and relaxation of the various fasciculi, which are disposed in almost every direction throughout the muscular wall of the stomach; and it seems to produce a kind of revolution of the contents of the stomach, sometimes in the direction of its length, and sometimes transversely. Its result is well shown in the hair-balls, which are occasionally found in the stomachs of animals, that have swallowed hair from time to time through licking their skins; the component hairs not being pressed together confusedly, but being worked together in regular directions, and so interwoven that they cannot be readily separated. As digestion proceeds, the dissolved fluid escapes, little by little, through the pyloric orifice, which closes itself firmly against the passage of solid bodies; and this motion continues, until the stomach is completely emptied; when it ceases, until food is again introduced. The bulk of the alimentary mass diminishes rapidly, as

Fig. 73.



Section of part of the Stomach of the Sheep, to show the demi-canal of the œsophagus; the mucous membrane is for the most part removed, to show the arrangement of the muscular fibres. At *a* is seen the termination of the œsophageal tube, the cut edge of whose mucous membrane is shown at *b*. The lining of the first stomach is shown at *c*, *c*; and the mucous membrane of the second stomach is seen to be raised from the subjacent fibres at *d*. At *e*, *e*, the lips of the demi-canal are seen bounding the groove, at the lower end of which is the entrance to the third stomach or many-plies.

the solvent process is near its completion; and the separation of the fluid product or chyme is aided by a peculiar action of the transverse fasciculi, which surrounds the stomach at about four inches from its pyloric extremity. These shorten in such a manner, as to produce a sort of hour-glass separation between the portions of the stomach on either side of it; and the fluid solution, being received by the pyloric or smaller portion, is pumped away through the pylorus; whilst the solid matter yet undissolved is retained in the larger division.

459. The degree in which these movements are dependent upon the nervous system, or are under its control or direction, has not yet been clearly ascertained. Distinct movements may be excited in the stomach of a Rabbit, if it be distended with food, by irritating the par vagum soon after the death of the animal; these movements seem to commence from the cardiac orifice, and then to spread themselves peristaltically along the walls of the stomach; but no such movements can be excited if the stomach be empty. On the other hand, there is distinct proof, that all the movements necessary to digestion may take place after the section of that nerve; although the first effect of the operation appears to be to suspend them completely. It is probable that the movements of the stomach are more regular and energetic in Herbivorous animals, whose food is difficult of digestion, than they are in the Carnivora, whose aliment is dissolved with comparative facility.

460. From the time that the ingested matter enters the Intestinal tube, it is propelled onwards by the peristaltic contractions of its muscular coat; which are excited, independently of all nervous influence, by the contact of the aliment, or by that of the secretions mingled with it in its passage along the canal. These last appear to have an important effect; for we find that, when the bile-duct is tied, so as to prevent the bile from entering the intestine, constipation always occurs; whilst an increase of the biliary and other secretions, consequent upon the action of mercury or upon any other cause, produces an increased peristaltic movement, and a more rapid discharge of the excrementitious matter. During the passage of the alimentary matter along the small intestine, as we shall see hereafter, a large proportion of its fluid is removed, by the absorbent power of the villi; and the residue is again brought, therefore, to a more solid consistence. This residue consists in part of those portions of the aliment, which are not capable of being dissolved or finely divided, so as to be received by the absorbents; and in part of the matters poured into the alimentary canal, by the various glands that discharge their contents into it, for the purpose of being carried out of the body. The feces, which are thus formed, are propelled through the large intestine, by the continued peristaltic action of its walls, until they arrive at the rectum.

461. That the ordinary peristaltic action of the intestinal canal is independent of nervous influence, is sufficiently proved by the fact, that it will continue when the tube is completely separated from all

connection with the nervous centres; as well as by the difficulty, already adverted to (§ 353), of exciting contractions in the muscular coat by any stimulation of its nerves. All the nerves of the intestine, from its commencement at the pyloric orifice of the stomach to its termination at the anus, are derived from the ganglia of the sympathetic system ; but there is evidence that those which influence its movements are really derived from the spinal cord (see Chap. XII). Although the *will* has no influence whatever on the peristaltic movement, yet the *emotions* seem to affect it; and it is probably to convey their influence that the intestinal canal is supplied with motor nerves. It is also furnished with sensory nerves, which form part of the trunks of the sympathetic system, but which really pass onwards to the brain; these do not, however, make us conscious of the passage of the alimentary matter along the canal, so long as it is in a state of health; but in various diseased conditions, they give rise to sensations of the most painful nature.

462. For the occasional discharge of the feces from the rectum, and for the retention of them at other times, we find the outlet or anal orifice, provided with an additional muscular apparatus, which is connected with the spinal system of nerves. The act of defecation is due to the pressure upon the contents of the rectum, which is occasioned by the combined contraction of the diaphragm and the abdominal muscles; whilst, on the other hand, the retention of the feces is due to the contractile power of the sphincter muscle, which surrounds the anus. The action of the sphincter ani, like that of the sphincter of the cardia, is a reflex one; dependent upon the connection of the muscle, by excitor and motor nerves, with the spinal cord. If the lower portion of the cord be destroyed, or if the nerves be divided, the sphincter loses its contractile power, and becomes flaccid. When in proper action, however, its power is sufficient to prevent the escape of the contents of the rectum ; until the expulsive force becomes very strong, in consequence either of the quantity of feces which has accumulated, or the acridity of their character. In either case, the impression made upon the mucous membrane of the rectum is conveyed to the spinal cord ; and, by a reflex motor impulse, the muscles of defecation are thrown into combined action, the resistance of the sphincter is overcome, and the feces are expelled. An unduly irritable state of the mucous membrane, or a disordered state of the excrementitious matter (resulting from the irritating character of the substances swallowed, from the acrid character of the secretions poured into the canal, or from an unusual change in the aliment during the digestive process), may occasion unduly frequent calls upon the muscles of defecation, which the sphincter is unable to resist. On the other hand, if the progress of the feces be delayed in the large intestines, by deficient peristaltic movement, they accumulate higher up, and the act of defecation is not excited.

463. Although the sphincter ani on the one hand, and the muscles of defecation on the other, are called into action by the reflex power of the spinal cord, and are so far involuntary in their operation, yet they are also in some degree subject (in Man at least) to the influence

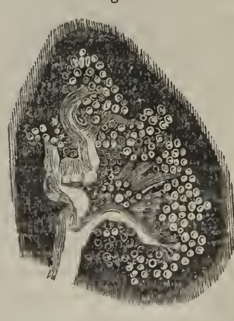
of the will. The resistance of the sphincter may be increased by a voluntary effort, when it is desired to retain the feces in opposition to the power of the expulsors; and it is only when the latter operate with excessive force that they can overcome it. On the other hand, the expulsors may be called into action, or may be aided, by the will, when the stimulus to their movement received through the spinal cord, would not otherwise be strong enough; and the feces may thus be evacuated by a voluntary effort, at a time when they would not otherwise be discharged.

4. *Of the Secretions poured into the Alimentary Canal, and of Changes which they effect in its contents.*

464. The whole Mucous Membrane of the Alimentary canal, from the mouth to the anus, is covered during health with that peculiar viscid secretion termed *mucus*, of which the characters have been already described (§ 237). This is formed, partly, on the free surface of the membrane itself, but chiefly in the numerous follicles or depressions by which that surface is increased; and it appears destined for the protection of the delicate, highly vascular membrane from undue irritation by the contact of the substances, which are passing through the alimentary tube. When these are unusually acrid, the secretion of mucus is augmented in quantity, and is increased in viscidity, so as to form an effective sheath to the membrane, which would otherwise suffer severely. When this secretion is deficient, the membrane is irritated by the contact of any but the blandest substances; and the class of remedies termed *demulcents* are useful in coating and protecting it.

465. During the mastication of the food in the mouth, the *Salivary* secretion is poured in, for the purpose of being mingled with it, and of rendering the act of mastication more easy. This secretion is formed by three pairs of glands,—the Parotid, the Sub-lingual, and the Submaxillary; these are composed of minute follicles, whose diameter is about 1-1000th of an inch, connected together by branches of their ducts, upon which they are set like grapes upon their stalk, surrounded by a plexus of blood-vessels, and bound together by areolar tissue. Within the follicles are the true secreting cells (§ 238); by whose growth and development, the material of the secretion is separated from the blood. These salivary cells are often to be recognized in the saliva; they must not, however, be confounded with the epithelium cells of the mucous membrane of the mouth, which are much larger. The fluid obtained from the mouth is not pure saliva; for the mucus of

Fig 74.



Lobule of Parotid Gland of new-born infant, filled with mercury; magnified 50 diameters.

the mouth itself is mingled with the secretion from the salivary glands. If the proportion of the former be considerable, it gives to the fluid of the mouth an acid reaction; whilst if the latter be predominant (which it is directly before, and during the act of eating), the fluid of the mouth has an alkaline reaction. It may be sometimes observed, that the saliva of the mouth will strike a blue colour with reddened litmus paper, whilst it turns blue litmus paper red; thus showing the presence both of an acid and an alkali in a state of imperfect neutralization.

466. The solid matter of the Salivary secretion is about 1 per cent. of the whole; and this consists in part of animal principles, and in part of saline substances. The animal matter consists of osmazome, mucus, and a peculiar substance termed *ptyaline* or salivary matter; which is soluble in water and insoluble in alcohol, and which is yet different from both albumen and gelatin. This substance appears to have a decided effect in producing the metamorphosis of certain alimentary substances, on which it acts like a *ferment*. Starch may be converted into sugar, and sugar into lactic acid, by its agency; and, if concentrated, it has a certain solvent power for casein, animal flesh, and other proteine-compounds. Its chemical nature has not yet been precisely determined. The saline constituents of the Saliva are nearly identical with those of the blood; the chlorides of sodium and potassium form considerably more than half; and the remainder consists chiefly of the tribasic phosphate of soda, to which the alkaline reaction of the fluid is due, with the phosphates of lime, magnesia, and iron. It is of the earthy phosphates, that the *tartar* which collects about the teeth is chiefly composed; the particles of these being held together by about 20 per cent. of animal matter: and the composition of the concretions, which occasionally obstruct the salivary ducts, is nearly the same.

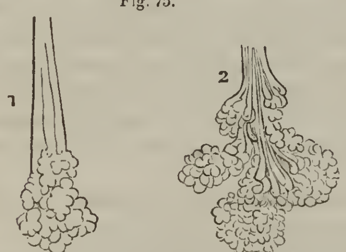
467. The quantity of Saliva formed during the twenty-four hours, has been estimated at from 15 to 20 ounces; but on this point it is impossible to speak with certainty. The secretion is by no means constantly flowing; indeed it is almost entirely suspended, when the masticator muscles and tongue are at perfect rest, unless it be excited by any mental cause; and hence it is, that the mouth becomes dry during sleep, if it be not kept closed. The flow of Saliva takes place just when it is most wanted; that is, when food has been taken into the mouth, and when the operation of mastication is going on. But it will also take place, especially in a hungry person, at the sight, or even at the idea, of savoury food; as is implied by the common expression of the "mouth watering" for such an object. The influence thus exercised over it by the emotional state of the mind, is probably conveyed to the salivary glands by the Fifth pair; which contains many of the gray or organic filaments; and which seems to take the place, in the Head, of a distinct lymphatic system.

468. Having been conveyed into the Stomach, the food is submitted to the action of the Gastric Fluid, which is secreted in the

walls of that organ. This fluid is not present in the empty stomach; its secretion being excited by the presence of food, or by the irritation of the walls of the organ by some solid body. In the intervals between the digestive process, the mucous membrane is of a light pink hue; but it becomes more turgid with blood, when the presence of food calls for the activity of its secreting processes. It is of a soft and velvet-like appearance; and it is constantly covered with a very thin transparent viscid mucus, which has neither acid nor alkaline reaction. By applying aliment or other stimulants to the internal coat of the stomach, and by observing the effect through a magnifying glass, numerous minute papillæ can be seen to erect themselves upon the mucous membrane, so as to rise through the coating of mucus; and from these is poured forth a pure, limpid, colourless, slightly viscid fluid, having a distinctly acid reaction, which is the Gastric juice. This fluid is secreted by follicles, which are lodged in the walls of the stomach, and which closely resemble those that elsewhere secrete mucus; but they are usually of more complex structure, and are more numerous.

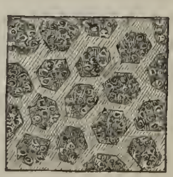
469. If the Mucous Membrane of the stomach be divided by a section perpendicular to its walls, it is seen to be made up, as it were, of tubular follicles closely applied to each other; their blind extremities resting upon the submucous tissue, and their open ends being directed towards the cavity of the stomach. In some situations, these tubuli are short and straight; in other parts they are longer, and present an appearance of irregular dilatation or partial convolution (Fig. 75, 1). This is their usual character, especially near the cardiac orifice of the stomach; but near the pyloric orifice they have a much more complex structure (Fig. 75, 2). These tubular follicles are arranged in bundles or groups, and are surrounded and bound

Fig. 75.



Glandulæ from the coats of the stomach, magnified 45 diameters;—1, from the middle of the stomach; 2, from the neighbourhood of the pylorus.

Fig. 76.



Portion of the mucous membrane of the stomach, showing the entrances to its secreting tubes, in pits upon its surface.

together by a fine areolar membrane; and this also serves to convey vessels from the submucous tissue, which ramify among the follicles, and supply the materials for their secretion. The number of tubuli in each group is by no means constant. The follicles do not, in general, open directly upon the surface; but into the bottom of small

depressions or pits, which may be seen to cover the membrane. These pits are more or less circular in form; and are separated from one another by membranous partitions, which vary in depth, and sometimes by pointed processes, which are capable of erecting themselves in the manner just described. The diameter of these pits varies from about 1-100th to 1-250th of an inch; it is always greatest near the pylorus. The number of the gastric follicles opening into each, is usually from three to five; but there are sometimes more.

470. The chemical composition of the Gastric fluid has been a subject of much discussion, and can scarcely yet be regarded as determined. Possibly it may vary in its nature, according to the state of the system, and the kind of animal from which it is obtained. That of Man has been usually stated to contain a sensible quantity of uncombined Muriatic and Acetic acids, to which its acid reaction has been attributed; whilst, on the other hand, it has been recently asserted, that the gastric fluid of the Dog contains no free muriatic acid, and that its acid reaction is due to the presence of the superphosphate of lime. The other inorganic ingredients of the Gastric fluid are nearly the same as those of the Saliva. It contains a peculiar organic compound, which, like Ptyaline, bears a considerable resemblance to albumen, but which is not identical with it; to this the name of *Pepsine* has been given. The properties of Pepsine have been principally studied in that form of it obtained from the mucous membrane of the stomach of the Pig, which bears a close resemblance to that of Man. When this membrane is digested in a large quantity of *warm* water, it is purified from the various soluble substances it may contain; but the pepsine is not taken up, as it is not soluble in warm water. By continuing the digestion in *cold* water, the pepsine is then extracted nearly pure. When this solution is evaporated to dryness, there remains a brown, grayish, viscid mass, having the appearance of an extract, and the odour of glue. A similar substance may be obtained by adding strong alcohol to a fresh solution of pepsine; for the latter is then precipitated in white flocks, which may be collected on a filter, and which produce a gray compact mass when dried. Pepsine enters into chemical combination with many acids; forming compounds which still redden litmus paper; and this appears to be its condition in the gastric juice.

471. The muriate and acetate of pepsine possess a very remarkable solvent power for albuminous substances. A liquid which contains only 17 ten-thousandths of acetate of pepsine, and 6 drops of muriatic acid per ounce, possesses solvent power enough to dissolve a thin slice of coagulated albumen, in the course of six or eight hours' digestion. With 12 drops of muriatic acid per ounce, the same quantity of white of egg is dissolved in two hours. A liquid which contains only half a grain of acetate of pepsine, and to which muriatic acid and white of egg are alternately added, so long as the latter is dissolved, is capable of taking up 210 grains of coagulated white of egg, at a temperature between 95° and 104.° The same acid with pepsine

dissolved blood, fibrin, meat, and cheese; whilst the acid without the pepsine requires a very long time to do so at ordinary temperatures. Very dilute muriatic acid, however, at the boiling point, dissolves these albuminous substances; and the solution has the same characters as that which is made by the agency of pepsine. The horny tissues,—such as the epidermis, horn, hair, &c.,—and the yellow fibrous tissue, are not affected by the acid solution of pepsine. It appears from these experiments, that the muriatic acid is the real solvent; and that the action of the pepsine is limited to *disposing* the albuminous matter for solution, producing in it a change analogous to that which may be effected by heat. Hence it may be considered, like ptyaline, as a sort of *ferment;* its office being to produce a tendency to change, in the substances on which it acts, without itself entering into new combinations with any of their elements.

472. These experiments appear to afford an explanation of the properties of the gastric fluid, as ascertained by direct experiment upon it. When drawn direct from the human stomach, it is found to possess the power of dissolving various kinds of alimentary substances, whilst these are submitted to its action at a constant temperature of 100° (which is about that of the stomach), and are frequently agitated. The solution appears to be in all respects as perfect as that which naturally takes place in the stomach; but a longer time is required to make it. This is easily accounted for by the difference of the conditions; for no ordinary agitation can produce the same effect with the curious movements of the stomach (§ 458); fresh gastric fluid is poured out, as it is wanted, during the natural process of digestion; and the continual removal of the matter which has been already dissolved by its exit through the pylorus, is of course favourable to the action of the solvent upon the remainder. The quantity of food, which a given amount of gastric fluid can dissolve, is limited; precisely as in the case of the acidulous solution of pepsine. The marked influence of temperature upon its action is shown by the fact, that fresh gastric fluid has scarcely any influence on the matter submitted to it, when the bottle is exposed to cold air, instead of being kept at a temperature of 100°. Hence the use of a large quantity of cold water at meal-times, or of ice afterwards, must retard the digestive process.

473. The pulpy substance, which is the product of the reducing action of the gastric juice, is termed *Chyme.* Its consistence will of course vary, in some degree, with the relative quantity of solids and liquids ingested. In general it is grayish, semifluid, and homogeneous; and possesses a slightly acid taste, but is otherwise insipid. When the food has been of a rich oily character, the Chyme possesses a creamy aspect; but when it has contained a large proportion of farinaceous matter, it has rather the appearance of gruel. The state in which the various alimentary principles exist in it, has not yet been accurately determined; the following, however, may be near the truth. —The proteine-compounds, whether derived from Animal or Vege-

table food, are all reduced to the condition of Albumen; a part of which is *dissolved*, whilst another portion is *suspended* in a very finely-divided state.—Gelatin will be dissolved or not, according to its previous condition; if it exist in a tissue from which it cannot readily be extracted, it will pass forth almost unchanged; but when ingested in a state of solution, it remains so; and if it have been previously prepared for solution by boiling, its solution is completed in the stomach.—The Gummy matters of Vegetables are dissolved, when they exist in a soluble form; as in the case of pure gum, pectine, and dextrine or starch-gum. The degree in which Starch, when its vesicles have not been ruptured by heat, is affected by the gastric fluid, seems to differ in different animals; the Ruminants and Granivorous Birds apparently possessing the power of crushing or dissolving the envelops of the starch-globules, whilst they pass through the alimentary canal of other Herbivora unchanged, and may be detected entire in their excrements.—Sugar is unquestionably taken up in solution, *as such*, in a healthy condition of the system; but it may undergo a previous change in the stomach, in disordered states of the digestive process.—Oily matters, whether of Animal or Vegetable origin, are reduced to the condition of an emulsion; being very finely divided, and their particles diffused through the chyme.—Most other substances, as resins, woody fibre, horny matter, yellow fibrous tissue, &c., pass unchanged from the stomach, and undergo no subsequent alteration in the intestinal canal; so that they are discharged among the feces as completely useless.

474. We have now to notice the conditions, under which the Gastric fluid is secreted; the knowledge of which is of great practical importance. We have seen that it is not poured forth, except when food is introduced into the stomach, or when its walls are irritated in some other mode; and there is reason to believe, that it is not previously secreted and stored up in the follicles, but that the act of secretion itself is due to the stimulus applied to the mucous membrane. The quantity of the fluid then poured into the stomach, however, is not regulated by the amount of food ingested, so much as by the wants of the system; and as only a definite quantity of food can be acted on by a given amount of gastric juice, any superfluity remains undissolved for some time,—either continuing in the stomach until a fresh supply of the solvent is secreted, or passing into the intestinal canal in a crude state, and becoming a source of irritation, pain, and disease. The use of a small quantity of salt, pepper, mustard, or other stimulating substances, appears to produce a gently stimulating effect upon the mucous membrane, and by causing an increased afflux of blood, to augment the quantity of the gastric fluid poured forth. Any excess of these or other irritants, however, produces a disordered condition of the mucous membrane, which is very unfavourable to the digestive process. It becomes red and dry, with an insufficient secretion of mucus; the epithelial lining is abraded, so that the mucous coat is left entirely bare; and irregular circumscribed patches of a

deeper hue, sometimes with small aphthous crusts, present themselves here and there on the walls of the stomach. Similar results follow excess in eating. When these changes are inconsiderable, the appetite is not much impaired, the tongue does not indicate disorder, and the digestive process may be performed; but if they proceed further, dryness of the mouth, thirst, accelerated pulse, foulness of the tongue, and other symptoms of febrile irritation, manifest themselves; and no gastric secretion can then be excited by the stimulus of food. Similar results may follow the excitement of the emotions; and those of a depressing nature seem especially to produce a pale flaccid condition of the mucous membrane, which is equally unfavourable to the due secretion of gastric fluid.

475. That the amount of the secretion is ordinarily proportioned to the wants of the system,—that the introduction of any superfluous aliment into the stomach is not only useless but injurious, as giving rise to irritation,—that incipient disorder of the stomach may occur, rendering it less fit than usual for the discharge of its important duties, without manifesting itself by the condition of the tongue,—that when the tongue *does* indicate disorder of the stomach, such disorder is usually considerable,—and that every particle of food ingested, in such states as prevent the secretion of gastric fluid, is a source of fresh irritation,—are truths which cannot be too constantly kept in mind. There can be no doubt that the habit of taking more food than the system requires, is a very prevalent one; and that it is persévered in because no evil result seems to follow. But when it is borne in mind that this habit must keep the stomach in a state of continual irritation, however slight, it can scarcely be doubted that the foundation is thus laid for future disorder, of a more serious kind. Two circumstances especially tend to maintain this practice in adults, independently of the mere disposition to gratify the palate. One is the habit of eating the same amount of food, as during the period of growth, when more was required by the system. The other is the custom of eating too fast; and this is injurious,—both by preventing sufficient mastication, and thus throwing on the stomach more than its proper duty,—and also by causing an over-supply of food to be ingested, before there is time for the feeling of satisfaction to replace that of hunger (§ 486).

476. The Chyme, upon quitting the stomach, passes into the duodenum; where it is mingled with the *biliary* and *pancreatic* secretions. The secretion of Bile is evidently a process of the highest importance in the economy; as we may judge alike from the size of the liver and the supply of blood it receives, and from the rapidly fatal effects of its suspension. Yet the chemical nature of the secretion has not yet been satisfactorily determined; and the destination of the fluid is still a matter of doubt. That a large part of it is purely excrementitious, and is poured into the intestinal tube for the purpose of being carried out of the body, can scarcely be questioned; but there is strong evidence, that a part of it is destined to be absorbed again, after performing some action of importance upon the contents of the alimentary

canal. There is a probability that a part of its function consists in rendering the fatty matter of the aliment more soluble; the nature of the secretion being such, as to give it in some degree the action of a soap. When fresh bile is mingled with newly-formed chyme, in a glass vessel, the mixture separates into three distinct parts;—a reddish-brown sediment at the bottom,—a whey-coloured fluid in the centre,—and a creamy pellicle at the top. The central and upper strata probably constitute the portion which is destined for absorption; whilst the sediment, partly consisting of the unreducible portion of the food, and partly of the biliary matter itself, is evidently excrementitious.

477. The composition of the Bile, and the structure of the organ which elaborates it, will be more fitly considered when the Excretions in general are treated of (Chap. IX.); at present we have only to consider its relation to the digestive process. In all but the very lowest animals, we find traces of a bile-secreting apparatus; and this is almost constantly situated in the immediate neighbourhood of the stomach. In many cases, the secretion is poured directly into the cavity of that organ; but in most, it is conveyed (as in Man) into the intestinal tube near its commencement. There are few instances in which the bile-ducts discharge themselves into the intestine low down, and still fewer in which they terminate near its outlet; and in these last, they appear also to discharge the functions of urinary organs. Hence it seems clear, from the disposition of the biliary apparatus, that it has a purpose to serve in connection with the digestive function, and is not destined solely for the elaboration of a product which is to be cast out of the body; since, if the latter were the case, that product would be carried out immediately, like the urinary excretion, and would not be discharged into the alimentary canal high up.—This conclusion is confirmed by experiment; for it has been shown by the recent experiment of Schwann, that, if the bile-duct be divided, and be made to discharge its contents externally through a fistulous orifice in the walls of the abdomen, instead of into the intestinal canal, those animals, which survive the immediate effects of the operation, subsequently die from inanition, almost as soon as if they had been entirely deprived of food.—The observation of disease in the human subject leads to similar conclusions; for, when the biliary secretion is deficient, or its flow into the intestine is obstructed, the digestive processes are evidently disordered; the peristaltic action of the bowels is not duly performed; the feces are white and clayey; and there is an obvious insufficiency in the supply of nutriment prepared for the absorbent vessels.

478. On the other hand, that one great object of the secretion is to withdraw from the blood certain products of the decomposition of the tissues, which would otherwise accumulate in it, and would be deleterious to its character, is shown by evidence yet more decisive. We find that the action of the Liver is *constant*, and not occasional, like that of the Salivary and Gastric glands; and that, if anything inter-

fere with the secreting process, and thereby cause the accumulation of the elements of the bile in the blood, the effects of their presence are immediately manifested in the disorder of other functions, especially those of the nervous system (§ 399); and the continued suspension of the function leads to a fatal result, unless the elements of the bile are drawn off (as sometimes happens) by the urinary organs. When the secreting action of the liver has once been performed, an obstruction to the discharge of the bile into the intestine does not seem to be so immediately injurious. The fluid accumulates, and distends the bile-ducts and the gall-bladder; and when they are completely filled, part of it is re-absorbed into the blood, apparently in a changed condition, since it does not *then* produce the same injurious effects as result from the accumulation of the same materials, previously to the action of the Liver upon them. The colouring-matter seems to be very readily taken back into the circulating system; and is deposited by it in almost every tissue of the body.

479. Although the secreting action of the Liver is constant, yet the discharge of bile into the intestine is certainly favoured by the presence of chyme in the latter. The purpose of the gall-bladder is obviously to permit the accumulation of bile, when it is not wanted in the intestine; and we find it most constantly present in those tribes of animals, which live upon animal food, and which therefore take their aliment at intervals; whilst it is more frequently absent in those herbivorous animals, in which the digestive process is almost constantly going on. The middle coat of the bile-ducts is clearly muscular, and has a peristaltic action like that of the intestinal canal; this action may be excited by galvanism, or by irritation of the branches of the Sympathetic nerve, by which it is supplied. The mucous coat of the ductus choledochus is disposed in valvular folds, in such a manner as to prevent the reflux of the bile or of the contents of the intestine; and a still further security is afforded by the valvular covering to the orifice of the duct, which is furnished by the mucous covering of the intestine itself. The flow of bile into the intestine, when its presence is needed there, is commonly imputed to the pressure of the distended Duodenum against the gall-bladder; but it is probable that the contractility of the muscular coat of the duct itself, which may be excited either through the sympathetic nerve, or by irritation at the orifice of the duct (as in the case of the Salivary glands) is the real cause of the discharge of the fluid. It is an interesting fact, which proves how much the passage of the Bile into the Intestine is dependent upon the presence of aliment in the latter, that the gall-bladder is almost invariably found turgid in persons who have died of starvation; the secretion having accumulated, through the want of demand for it, although there was no obstacle to its exit.

480. The *Pancreatic* secretion appears to have nearly the same qualities as Saliva; the proportion of solid matter, however, being usually greater. Of its uses in the digestive process, nothing definite can be stated.

481. During the passage of the contents of the Intestine, now augmented by the biliary secretion, along the canal, the nutritious portion is gradually withdrawn by the absorbent vessels on its walls; and the excrementitious matter alone remains. This is increased in amount by the products of the secretion of the various glandulæ, with which the mucous lining of the intestines is studded. As their function, however, is obviously to get rid of decomposing matter from the system, rather than to contribute in any way to the preparation of the nutritive materials, it will be more properly considered hereafter (Chap. XI). Many of the lower animals are furnished, at the part where the small intestine enters the large, with a *cæcum*, resembling that which in Man is termed the vermiform appendage of the cæcum, but greatly exceeding it in size. Sometimes we find two cæca instead of one; and these are much prolonged, so as to form tubes of considerable length. It has been ascertained that, in herbivorous animals, a distinctly acid secretion is formed by the cæcum, during the digestive process; and there is reason to believe, that the food there undergoes a second process, analogous to that to which it has been submitted in the stomach, and fitted to extract from it any undissolved alimentary matter it may still contain. There is no reason to believe, however, that any such process takes place in Man, whose real cæcum is rudimentary,—the part of the intestine which has received the name, being merely the dilated commencement of the colon. The act of defecation, by which the excrementitious matter is discharged, has been already noticed (§ 462); the Absorption of nutritive matter will be treated of in the succeeding Chapter.

5. *Of Hunger, Satiety, and Thirst.*

482. The want of solid aliment is indicated by the sensation of Hunger; and the deficiency of fluid by that of Thirst. On the other hand, the presence of a sufficiency of food or liquid in the stomach is indicated by the sense of Satiety. These sensations are intended as our guides, in regard to the amount of aliment we take in. What is the real seat of these sensations, and on what conditions do they depend?

483. The sense of Hunger is referred to the stomach, and seems *immediately* to depend upon a certain condition of that organ; but what that condition is, has not yet been precisely ascertained. It is not produced by mere emptiness of the stomach, as some have supposed; for, if the previous meal have been sufficient, the food passes entirely from the cavity of the stomach, before a renewal of the sensation is felt. It cannot be due to the action of the gastric fluid upon the coats of the stomach themselves; because this fluid is not poured into the stomach, except when the production of it is stimulated by the irritation of the secreting follicles. It has been attributed to distension of the gastric follicles by the secreted fluid; but there is no evidence that the fluid is secreted before it is wanted; and, moreover,

it is well known that mental emotion can dissipate in a moment the keenest appetite, and it is difficult to imagine how this can occasion the emptying of the follicles. Perhaps the most satisfactory view is that, which attributes the sense of hunger to a determination of blood to the stomach, preparing it for the secretion of gastric fluid; since this is quite adequate to account for the impression made upon the nerves; and it accords with what has just been stated of the influence of mental emotions, since we know that these have a powerful effect upon the circulation of blood in the minute vessels (§ 603).

484. Although the sense of Hunger is immediately dependent, in great part at least, upon the condition of the stomach, yet it is also indicative of the condition of the general system; being extremely strong, when the body has undergone an unusual waste without a due supply of food, even though the stomach be in a state of distension; whilst it is not experienced, if, through the general inactivity of the system, the last supply has not been exhausted, even though the stomach has been long empty. It is well known, that when food is deficient, the attempt to allay the pangs of hunger by filling the stomach with non-nutritious substances, is only temporarily successful; the feeling soon returning with increased violence, though it has received a temporary check. The reason for this is obviously, that the general system has received no satisfaction, although the stomach has been caused to secrete gastric fluid by the contact of solid matter with its walls, so that the state on which hunger immediately depends, has been for a time relieved. This state is soon renewed, unless the solid matter introduced into the stomach be of an alimentary character, and be dissolved and carried into the system.

485. When the food is nutritious in its character, but of small bulk, experience has shown the advantage of mixing it with non-nutritious substances, in order to give it bulk and solidity; for if this be not done, it does not exert its due stimulating influence upon the stomach; the gastric juice is not poured forth in proper quantity; and the result is, that neither is the sense of hunger relieved, nor are the wants of the body satisfied. Thus the Kamschatdales are in the habit of mixing earth or saw-dust with the train-oil, on which alone they are frequently reduced to live. The Veddahs or wild hunters of Ceylon, on the same principle, mingle the pounded fibres of soft and decayed wood with the honey on which they feed when meat is not to be had; and on one of them being asked the reason of the practice, he replied, "I cannot tell you, but I know that the belly must be filled." It has been found that soups and fluid diet are not more readily converted into chyme than solid aliment, and are not alone fit for the support of the body in health; and it is often to be observed, in disordered states of the stomach, that it can retain a small quantity of easily-digested solid food, when a thin broth would be rejected.

486. The sense of Satiety is the opposite of Hunger; and like it, depends on two sets of conditions,—the state of the stomach, and that of the general system. It is produced in the first instance by the

ingestion of solid matter into the stomach, which gives rise to the feeling of fullness; but this is only a part of the sensation which ought to be experienced; and it is only when the act of digestion is being duly performed, and nutritive matter is being absorbed into the vessels, that the peculiar feeling of satisfaction is excited, which indicates that the wants of the system at large are being supplied.—It has been very justly remarked by Dr. Beaumont, that the cessation of the demand set up by the system, rather than the positive feeling of satiety, should be the guide in regulating the quantity of food taken into the stomach. The sense of satiety is beyond the point of healthful indulgence; and is Nature's earliest indication of an abuse and overburdening of her powers to replenish the system. The proper intimation is the pleasurable sensation which is experienced, when the cravings of the appetite are first allayed; since, if the stomach be sufficiently distended with wholesome food, for this to be the case, it is next to certain that the digestion of that food will supply what is required for the nutrition of the body. It is only when the substance with which the stomach is distended, is *not* of a digestible character, that the feelings excited by the state of that organ are anything but a correct index of the wants of the system.

487. The Par Vagum is evidently the nerve, which conveys to the sensorium the impression of the state of the *stomach*, and which is therefore the immediate excitor of the sensation of hunger, or of the feeling of satiety. But it is evident from experiments upon animals, that it is not the only source, through which they are incited to take food, and are informed when they have ingested enough; and it is probable that the Sympathetic nerve is the channel, through which the wants of the *system* are made known, and through which, in particular, the feeling of general exhaustion is excited, that is experienced when there has been an unusual waste, or when the proper supply has been too long withheld.

488. The conditions of the sense of Thirst are very analogous to those of hunger; that is, it indicates the deficiency of fluid in the body at large; but the immediate seat of the feeling is a part of the alimentary canal,—not the stomach, however, but the fauces. It is relieved by the introduction of fluid into the circulating system, through *any* channel; whilst the mere contact of fluids with the surface to which the sensation is referred, produces only a temporary effect, unless absorption take place. If liquids be introduced into the stomach by an œsophagus-tube, they are just as effectual in allaying thirst, as if they were swallowed in the ordinary manner; and the same result follows the injection of fluid into the veins, (as was most remarkably the case when this method of treatment was practised in the Asiatic Cholera,) or the absorption of fluid through the skin or the lower part of the alimentary canal. The deficiency of fluid in the body may arise,—and Thirst may consequently be induced,—either by an unusually small supply of fluid, or by excessive loss of the fluids of the body, as by perspiration, diarrhœa, &c. But it may also be

occasioned by the impression made by particular kinds of food or drink upon the alimentary canal; thus salted or highly-spiced meat, fermented liquors when too little diluted, and other similar irritating agents, excite thirst; the purpose of which sensation is evidently to cause the ingestion of fluid, by which these substances may be diluted, and their irritating action prevented.

CHAPTER V.

ABSORPTION AND SANGUIFICATION.

1. *Absorption from the Digestive Cavity.*

489. So long as the Alimentary matter is contained in the digestive cavity, it is as far from being conducive to the nutrition of the system, as if it were in contact with the external surface. It is only when absorbed into the vessels, and carried by the circulating current into the remote portions of the body, that it really becomes useful in maintaining the vigour of the system, by replacing that which has decayed, and by affording the materials for the various organic processes which are continually going on. Among the Invertebrated animals, we find the reception of alimentary matter into the circulating system to be entirely accomplished through the medium of the *veins*, which are distributed upon the walls of the digestive cavity. We not unfrequently observe, that the intestinal tube is completely enclosed within a large venous sinus, so that its whole external surface is bathed with blood; and into this sinus, the alimentary materials would appear to transude, through the walls of the intestinal canal, to become mingled with the blood, and to be conveyed with its current into the remote portions of the body. Among the Vertebrata, we find an additional set of vessels, interposed between the walls of the intestine and the sanguiferous system, for the purpose, as it would seem, of taking up that portion of the nutritive matter which is not in a state of perfect solution, and of preparing it for being introduced into the current of the blood. These vessels are the *lacteals* or *absorbents*. They are very copiously distributed upon the walls of the small intestine, commencing near the entrance of the biliary and pancreatic ducts; the walls of the large intestine are less abundantly supplied with them, and they are not to be met with at all on the walls of the stomach.

490. Nevertheless it is quite certain, that substances may pass into the current of the circulation, which have been prevented from passing further than the stomach; thus, if a solution of Epsom-salts be introduced into the stomach of an animal, and its passage into the

intestine be prevented by a ligature around the pylorus, its purgative action will be exerted nearly as soon, as if the communication between the stomach and intestines had been left quite free; or if a solution of prussiate of potash be introduced into the stomach under similar circumstances, the presence of that salt in the blood may be speedily demonstrated by chemical tests.

491. This passage of substances in a state of perfect solution, from the stomach into the blood-vessels, is probably due to the operation of that peculiar modification of Capillary Attraction, which is called *Endosmose.* When two fluids differing in density are separated by a thin animal or vegetable membrane, there is a tendency to mutual admixture through the pores of the membrane; but the less dense fluid will transude with much greater facility than the more dense; and consequently there will be a considerable increase on the side of the denser fluid; whilst very little of this, in comparison, will have passed towards the less dense. When one of the fluids is contained in a sac or cavity, the flow of the other towards it is termed Endosmose, or flow-inwards; whilst the contrary current is termed Exosmose or flow-outwards. Thus if the cæcum of a fowl, filled with syrup or gum-water, be tied to the end of a tube, and be immersed in pure water, the latter will penetrate the cæcum by Endosmose, and will so increase the volume of its contents, as to cause the fluid to rise to a considerable height in the attached tube. On the other hand, a small proportion of the gum or syrup will find its way into the surrounding fluid by Exosmose. But if the cæcum were filled with water, and were immersed in a solution of gum or sugar, it would soon be nearly emptied,—the Exosmose being much stronger than the Endosmose. It is in this manner that we may cause the flattened corpuscles of the blood to be distended into spheres, by treating them with water; or may empty them almost completely, by immersing them in syrup (§ 216); since their contents are more dense than the surrounding fluid in the first case, so that they will be augmented by Endosmose; whilst they are less dense in the second, so as to be diminished by Exosmose.

492. Now it seems to be in this manner, that substances contained in the cavity of the stomach, and perfectly dissolved by its fluids, are received into the blood-vessels; for as the blood is the fluid of greater density, it will have a tendency to draw towards it, by Endosmose, the saline and other matters, which are in a state of perfect solution in the stomach. The mucous membrane, which forms the inner wall of that organ, is most copiously supplied with blood-vessels; partly, indeed, that they may afford the materials of the gastric secretion; but partly, also, that they may take up the substances, which are capable of entering the circulating current by this direct channel. That this act of absorption is principally effected by the veins rather than by the arteries, appears from several considerations. The walls of the former are much thinner than those of the latter. Moreover, the former are usually distributed nearer to the surface; whilst the latter are

more deeply-seated. And the direction of the passage of the blood in the former is favourable to the act of absorption, whilst in the latter it is the reverse; for the blood in the arteries is passing from large trunks, through which it flows with facility, into the innumerable subdivisions and ramifications of the capillary system, in which the resistance to its flow is very much increased; whilst in the veins, the numerous streams flowing through the capillaries are uniting and converging into main trunks of greatly-increased capacity, so that the resistance is greatly diminished; and it is easily shown on Physical principles, that the former condition presents a direct obstacle to absorption, whilst the latter as directly favours it. For if a current of fluid be made to pass through a horizontal tube, which undergoes an enlargement at one part of its course, so that the fluid passes from the smaller to the larger portion, and if a small tube be made to open into the enlarged part, and to dip down vertically into a basin below, the fluid of that basin will be caused to rise in the small tube, so as to be drawn into the current that is flowing through the horizontal pipe,—and this with a force proportional to the amount of its enlargement, and to the rapidity of the current that is flowing through it.

493. Although it is difficult to speak with certainty on the point, yet there appears a strong probability that, both in the stomach and intestinal tube, the absorption of nutritive matters in a state of *perfect solution*,—such as gum, sugar, pectine, gelatin, and soluble albumen,—is thus accomplished through the medium of the veins; which also take up the chief supply of water that is required by the system. It is difficult else to see the purpose of the extraordinary vascularity of the mucous membrane, and in particular of those filaments or narrow folds, termed villi, which so thickly cover its surface. Each of these villi is furnished with a plexus of minute blood-vessels, of which the larger branches may even be seen with the naked eye, when they are distended with blood or with a coloured injection. By these villi, the vascular surface of the mucous membrane is enormously extended. In Man, they are commonly cylindrical or nearly so, and are from about a quarter of a line to a line and a half in length; but in many of the lower animals they are spread out into broader laminæ at the base, and are connected together so as to form ridges or folds.—It appears from the experiments of MM. Tiedemann and Gmelin, that when various substances were mingled with the food, which, by their colour, odour, or chemical properties, might be easily detected,—such as gamboge, madder, rhubarb, camphor, musk, assafetida, and saline compounds,—they were seldom found in the chyle, though many of them were detected in the blood and in the urine. The colouring matter appeared to be

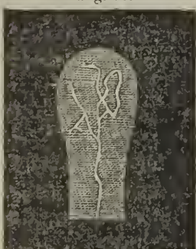
Fig. 77.

Distribution of Capillaries in the Villi of the Intestine.

seldom absorbed at all; the odorous substances were generally detected in the venous blood and in the urine, but not in the chyle; whilst, of the saline substances, many were found in the blood and in the urine, and only a very few in the chyle.

494. Every one of the intestinal Villi, however, also contains the commencement of a proper *absorbent* vessel; and this system of vessels has received the name of *lacteal*, on account of the milky aspect of the fluid which is found within it. The accompanying figure represents the appearance offered by the incipient lacteals in a villus of the jejunum of a young man, who had been hung soon after taking a full meal of farinaceous food. The trunk that issues from the villus is formed by the confluence of several smaller branches, whose origin it is difficult to trace; but it is probable that they form loops by anastomosis with each other, so that there is no proper free extremity in any case. It is quite certain that the lacteals never open by free orifices upon the surface of the intestine, as was formerly imagined. From the researches of Mr. Goodsir, already referred to, it appears that these loops are imbedded in a mass of cells, which are the real agents in the selection of the materials that are destined to be conveyed into the lacteals; and that the growth of these cells is the first stage of the process, by which the nutritive matters that are in a state of very fine *division*, but not in perfect *solution*, are received into the system (§ 241). When these cells have completed their office, and have passed through the term of their lives, they yield their contents to the absorbent vessels, either by bursting or by deliquescence; and thus the substances which they have selected and combined by their own processes of growth, are delivered to the current in which they are to undergo further transformations, and to be made subservient to the nutrition of the general system.

Fig. 78.



One of the intestinal villi, with the commencement of a lacteal.

495. It is particularly important to keep in view the difference between the two modes by which alimentary substances are introduced into the system, when we are treating those disordered states in which the digestive process is imperfectly performed, or altogether suspended. There can be little doubt, that the *immediate* cause of death, in many diseases of exhaustion, is the want of power to maintain the heat of the body; the stomach not being able to dissolve food, and the functions of the lacteals being altogether suspended, by the non-development of the absorbing cells, so that the inanition is as complete as if food were altogether withheld. Now under such circumstances, it becomes a matter of greatest importance to present a supply of combustible matter, in such a form that it may be introduced into the circulating system by simple Endosmose; and the value which experience has assigned to *weak* broths and *thin* fari-

naceous solutions, and still more, to diluted alcoholic drinks, frequently repeated, under such circumstances, seems to depend in great part upon the facility with which they may be thus absorbed. The good effects of alcohol, cautiously administered, are no doubt owing in part to its specific influence upon the nervous system; but that they are also due to its heat-producing power, appears from the results of the administration of frequently-repeated doses, in states of utter exhaustion,—the temperature of the body being kept up so long as they are continued, and falling when they are intermitted. As the alcohol is thus burned off, nearly as fast as it is introduced, it never accumulates in sufficient quantity to produce its usual violently-stimulating effects upon the nervous system.

2. *Passage of the Chyle along the Lacteals, and its admixture with the Lymph collected from the general System.*

496. The Lacteal vessels, which commence on the surface of the intestines, run together on their walls, and form larger trunks, which converge and unite with each other in the mesentery; and the main trunks thus formed then enter certain bodies, which are commonly known as the "mesenteric glands." Their structure, however, does not seem to correspond with that of the proper glands; as they are

Fig. 79.

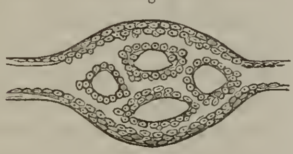
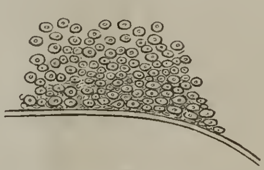


Diagram of a lymphatic gland, showing the intra-glandular network, and the transition from the scale-like epithelia of the extra-glandular lymphatics, to the nucleated cells of the intra-glandular.

Fig. 80.



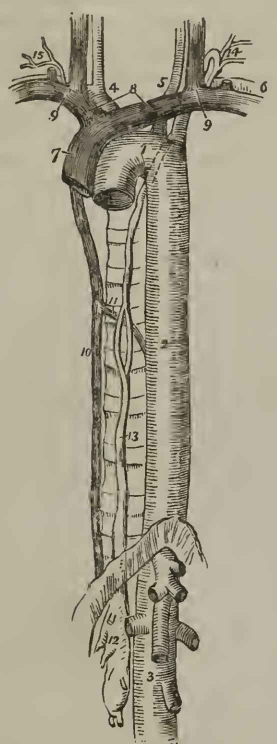
Portion of intra-glandular lymphatic, showing along the lower edge the thickness of the germinal membrane, and, upon it, the thick layer of glandular epithelial cells.

simply composed of lacteal trunks, convoluted into knots, and dilated into larger cavities, amongst which blood-vessels are minutely distributed. These blood-vessels have no direct communication with the interior of the lacteals; but are separated from them by the membranous walls of both sets of tubes. The epithelium, which lines the absorbent vessel, undergoes a marked change where the vessel enters the gland, and becomes more like that of the proper glandular follicles in its character. Instead of being flat and scale-like, and forming a single layer in close apposition with the basement-membrane, as it does in the lacteal tubes before they enter the gland and after they have emerged from it, we find it composed, within the gland, of numerous layers of spherical nucleated cells (Figs. 79 and 80); of which the superficial ones are easily detached, and appear to be

identical with the cells that are found floating in the chyle. The purpose of these cells will be presently inquired into.

497. After emerging from the mesenteric glands, the lacteal trunks converge, with occasional union, until they discharge their contents into the *receptaculum chyli*, which is situated at the front of the body of the second lumbar vertebra. Into the same cavity are poured the contents of a part of the other division of the Absorbent system; which is distributed through the body in general, and which, from the transparency of the fluid or lymph it contains, is termed the *lymphatic* system. From the receptaculum chyli arises the *thoracic duct;* which passes upwards in front of the spine, receiving other lymphatic trunks in its course, to terminate at the junction of the left subclavian and jugular veins; where it delivers its contents into the sanguiferous system. A smaller duct receives some of the lymphatics of the right side, and there terminates at a corresponding part of the venous system; but it does not receive any of the contents of the lacteals.

Fig. 81.



The course and termination of the thoracic duct. 1. The arch of the aorta. 2. The thoracic aorta. 3. The abdominal aorta; showing its principal branches divided near their origin. 4. The arteria innominata, dividing into the right carotid and right subclavian arteries. 5. The left carotid. 6. The left subclavian. 7. The superior cava, formed by the union of, 8, the two venæ innominatæ; and these by the junction, 9, of the internal jugular and subclavian vein at each side. 10. The greater vena azygos 11. The termination of the lesser in the greater vena azygos. 12. The receptaculum chyli; several lymphatic trunks are seen opening into it. 13. The thoracic duct, dividing opposite the middle of the dorsal vertebræ into two branches, which soon reunite; the course of the duct behind the arch of the aorta and left subclavian artery is shown by a dotted line. 14. The duct making its turn at the root of the neck, and receiving several lymphatic trunks previously to terminating in the posterior aspect of the junction of the internal jugular and subclavian vein. 15. The termination of the trunk of the ductus lymphaticus dexter.

498. The lymphatic system is evidently allied very closely to the lacteal, in its general purposes; and makes its first appearance in the same class of animals, namely, in Fishes. The vessels of which it is composed are distributed through most of the softer tissues of the body, and are particularly abundant in the skin. They have never been found to commence by closed or open extremities; but seem to

form a network, from which the trunks arise. In their course they pass through glands, disposed in different parts of the body, which exactly resemble in structure those which are found upon the lacteals in the mesentery. And they at last terminate, as already shown, in the same general receptacle with the lacteals. Hence it cannot be reasonably doubted, that the fluid which they absorb from the various tissues of the body, is destined to become again subservient to nutrition; being poured back into the current of the blood, along with the new materials, which are now for the first time being introduced into it. That the special Absorbent apparatus of Vertebrated animals has for part of its functions to effect a change in the materials absorbed, and thus to aid in fitting them for introduction into the blood, seems apparent from the facts of Comparative Anatomy; which show that, the more distinct the blood is from the chyle and lymph, the more marked is the provision for delaying the latter in the absorbent system, and for subjecting it to preliminary change.

499. The course of the lymphatic and lacteal vessels in *Fishes* is short and simple; they are not furnished with glands; and they pour their contents into the blood-vessels at several different parts of the body. In this class the blood contains fewer red corpuscles, and its coagulating power is feebler than in any other Vertebrata. And in the lowest tribes, in which the Vertebrated character is almost entirely wanting, and in which the blood is almost pale, no special absorbent system has yet been discovered. In *Reptiles*, the length of the absorbent vessels is remarkably increased by their doublings and convolutions; so that the system appears to be more highly developed than in either of the warm-blooded classes. But this superiority is not real; for there is yet no trace of the glands, which concentrate, as it were, the assimilating power of a long series of vessels. Moreover, we often find the lymphatics of this class furnished with pulsating dilatations, or *lymphatic hearts;* which have for their office to propel the lymph into the venous system. In the Frog there are two pairs of these; one situated just beneath the skin (through which its pulsations are readily seen in the living animal), immediately behind the hip-joint; the other pair being more deeply seated at the upper part of the chest. The former receive the lymph of the posterior part of the body, and pour it into the veins proceeding from the same part; the latter collect that which is transmitted from the anterior part of the body and head, and empty their contents into the jugular vein. Their pulsations are totally independent of the action of the heart, and of the respiratory movements; since they continue after the removal of the former, and for an hour or two subsequently to the death and complete dismemberment of the animal. They usually take place at the rate of about sixty in the minute; but they are by no means regular, and are not synchronous on the two sides.

500. In *Birds*, we find the absorbent system existing in a more perfect form; its diffused plexuses and convolutions being replaced by glands; in which the contained fluid is brought into closer proxi-

mity with the blood; and in which it is subjected to the influence of assimilating cells. These, however, are not very numerous; being principally found on the lymphatics of the upper extremities. The absorbents, in this class, terminate principally by two thoracic ducts, one on each side, which enter the jugular veins by several orifices. There are, however, two other entrances, as in Reptiles, into the veins of the lower extremity; and these are connected with two large dilatations of the lymphatics, which are evidently analogous to the lymphatic hearts of Reptiles, but which have little or no power of spontaneous contraction.—In *Mammalia*, the absorbent system presents itself in its most developed and concentrated state. The vessels possess firmer walls, and are more copiously provided with valves, than in the classes beneath; and the glands are much more numerous, particularly upon the vessels that receive or imbibe substances from without,—as those of the digestive cavity, the skin, and the lungs. The terminations of the absorbents in the veins are usually restricted, as in Man, to the single point of entrance of the thoracic duct on either side; but they are sometimes more numerous; and certain variations in the arrangement of the thoracic ducts, which occasionally present themselves as irregularities in Man, are the ordinary conditions of these parts in some of the lower Mammalia.

501. With regard to the source of the matters absorbed by the lymphatics, it is difficult to speak with certainty. We shall presently see that their contents bear a close resemblance to the fluid element of the blood, or "liquor sanguinis," in a state of dilution; and it is very probable that they partly consist of the residual fluid, which, having escaped from the blood-vessels into the tissues, has furnished the latter with the materials of their nutrition, and is now to be returned to the former. But they may include, also, those particles of the solid frame-work, which have lost their vital powers, and which are not fit therefore to be retained as components of the living system, but which have not undergone a degree of decay which prevents them from serving, like matter derived from the dead bodies of *other* animals, as a material for reconstruction, when it has been again subjected to the organizing process.

502. It was formerly supposed (and the doctrine was particularly inculcated by the celebrated John Hunter), that the office of the Lymphatic system is to take up and remove all the effete matter, that is to be cast out of the body, being no longer fit for its nutrition. But for such a supposition there is no adequate foundation. It seems absurd to imagine, that this effete matter would be mingled with the newly-ingested aliment, and would be poured back with it into the general current of the circulation, instead of being at once carried out of the system. And the idea is directly negatived, as we shall presently see, by the actual composition of the lymph drawn from these vessels; the solid matter of which consists, in great part at least, of substances of a nutritive character. It is true that other substances are occasionally found in the lymphatics; thus, when the gall-bladder

and bile-ducts are over-distended with bile, in consequence of some obstruction to its exit, the lymphatics of the liver are found to contain a biliary fluid. In like manner, the lymphatics in the neighbourhood of a large abscess have been found to contain pus. When the limb of an animal, round the upper part of which a bandage is tied, is kept for some hours in tepid milk, the lymphatics of the skin are found distended with that fluid. And when saline solutions are applied to the skin, they are usually detected more readily in the lymphatics, than in the veins. But these facts only prove, that the lymphatics very readily imbibe soluble substances with which they are in proximity; and this imbibition seems to take place on the same physical principles, as the imbibition of soluble substances by the veins of the intestinal canal.

503. The more ready absorption of such substances by the lymphatics, than by the veins, of the cutaneous surfaces,—contrary to what obtains in the alimentary canal,—is easily accounted for, by the very abundant distribution of the lymphatics in the skin, and the ready access which fluids can obtain to their walls. In other tissues it is different; thus it appears that saline matters injected into the lungs are detected much sooner in the serum of the blood than they are in the lymph; and make their appearance earlier in the left cavities of the heart, to which they would be conveyed by the pulmonary vein, than in the right, which they would reach through the thoracic duct and descending cava. This is obviously due to the minute distribution of the blood-vessels upon the walls of the air-cells; which makes them far more ready channels for the imbibition of fluid, than the lymphatics could be.—In regard to the occasional absorption of pus from the cavity of an abscess or of an open ulcer, by the lymphatics, it is to be remarked that the absorbent vessels must themselves probably be laid open by ulceration; since in no other way can we understand the entrance of globules, so large as those of pus, into their interior.

504. In regard to the cause of the movement of the chyle and lymph along the absorbent vessels, from their commencement to their termination in the central receptacle, no very definite account can be given. The middle coat of these vessels has a fibrous texture; and the fibres bear some resemblance to that of the non-striated muscle. In the thoracic duct, this fibrous structure is more evident; and distinct contractions have been excited in it, by irritating the sympathetic trunks from which it receives its nerves, and the roots of the spinal nerves with which those trunks are connected. Hence it seems probable, that there is a sort of peristaltic contraction of the walls of the absorbents, analogous to that which takes place in the intestinal tube, serving to drive their contents slowly onwards; their reflux being prevented by the valves, with which they are copiously furnished. Moreover, it is probable that the general movements of the body may concur with the contractile power of the absorbent vessels themselves, to urge their contents onwards; for almost every change in position

must occasion increased pressure on some portion of them, which will propel the fluid contents in the sole direction permitted by the valves, and thus give them an additional impulse towards the trunks, in which they are collected for delivery into the blood-vessels.

3. *Of the Spleen, and other Glandular Appendages to the Lymphatic System.*

505. The structure and functions of the Spleen, and of certain other organs allied to it in character, have been among the most obscure subjects in Anatomy and Physiology; and they are far from having been yet fully elucidated. There seems sufficient evidence, however, for regarding them in the light of appendages to the Lymphatic system, and as concerned, like it, in the process of Sanguification, or the preparation of Blood. Hence this appears to be the most appropriate place, for such a brief notice of them, as the present state of our knowledge admits.

506. The *Spleen* is certainly to be regarded as an organ of compound structure, having at least two sets of functions to fulfil. It is essentially composed of a fibrous membrane, which constitutes its exterior envelop, and which sends prolongations in all directions across its interior, so as to divide it into a number of minute cavities or follicles of irregular form. These *splenic follicles* communicate freely with each other, and with the splenic vein, and they are lined by a continuation of the lining membrane of the latter. The partitions between the follicles are formed, not only by these membranes, but by the peculiar *parenchyma* of the Spleen; and this seems to be made up of reticulations of blood-vessels and lymphatics, with a large quantity of minute globules or incipient cells, of about half the diameter of blood-corpuscles, which lie in the meshes of the capillary network, and which seem to be in intimate connection with the lymphatics. Lying in the midst of this parenchyma, there are found a large number of bodies, about one-third of a line in diameter, which are known as the Malpighian bodies of the Spleen. These resemble lymphatic glands in miniature, being composed of convoluted masses of blood-vessels and lymphatics, united by elastic tissue; and the lymph they contain is rendered somewhat milky by the large number of the lymph-corpuscles that float in them, although the fluid of the afferent lymphatics is quite clear;—so that the correspondence both in structure and function seems to be exact.

507. The *parenchymatous* and the *cellated* structures do not seem to bear any constant proportion to each other; thus the former prevails most in Man, and the latter in the Herbivora. The walls of the follicles are so elastic, that their cavities may be greatly distended with a very moderate force,—the Spleen of the sheep, which weighs about 4 oz., being easily made to contain about 30 oz. of water. This peculiar distensibility evidently points to the Spleen as a kind of reservoir, connected with the Portal circulation, for the purpose of reliev-

ing the portal vessels from undue pressure or distension, under a great variety of circumstances. The portal system is well known to be destitute of valves, so that the splenic vein communicates freely with the whole of it; and thus, if any obstruction exist to the flow of blood through the liver, or any peculiar pressure elsewhere prevents the mesenteric veins from dilating to their full extent, the general circulation is not disturbed,—the Spleen affording a kind of safety-valve. That any cause of congestion of the Portal system peculiarly affects the Spleen, has been proved by experiment; for, after the portal vein has been tied, the spleen of an animal that previously weighed only 2 oz., has been found to increase 20 oz. Further, in Asphyxia, when the circulation of blood is checked in the Lungs, and when the stagnation extends itself backwards to the right side of the heart, to the vena cava, and thence to the portal system, the Spleen is often found after death to be enormously distended with blood. And in the cold stage of intermittent fever, in which a great quantity of blood is driven from the surface towards the internal organs, the Spleen receives a large portion of it, so that its increased size becomes quite perceptible; and in cases of confirmed Ague, the Spleen becomes permanently enlarged, forming what is popularly known as the "ague-cake."—Again, the Spleen appears to serve as a reservoir, into which superfluous blood may be carried, during the digestive process. When the alimentary canal is distended with food, and a great afflux of arterial blood takes place to the mucous membrane, the veins of the portal system will be liable to increased pressure from without, whilst their contents will be augmented by the quantity of fluid newly absorbed from the alimentary canal. In this, as in the preceding cases, the distensibility of the spleen makes it a kind of safety-valve, by which undue distension of the portal system is relieved. It has been ascertained that its maximum volume is attained about five hours after a meal, when the process of chymification is at an end, and that of absorption is taking place with activity; and the increase is proportional rather to the amount of the fluids ingested, than to that of the solids.

508. But besides this safety-valve function, there can be little question that the Spleen performs another, which corresponds with the function of the lymphatic glands in general. The identity in structure between its Malpighian bodies, and the ordinary lymphatic glands, is such as clearly points to this inference; and it is confirmed by this remarkable fact, which has been ascertained by recent experiments,—that after the spleen has been extirpated, the lymphatic glands of the neighbourhood increase in size, and cluster together as they enlarge, so as to form an organ that at least equals the original spleen in volume. This circumstance explains the reason of the almost invariable *negative* result of the extirpation of the spleen; for although the operation has been frequently practised, with the view of determining the functions of the organ by the symptoms presented by the animals after its re-

moval, no decided change in the ordinary course of their vital phenomena has ever been observed, and the health, if at all disturbed for a time, is afterwards completely regained. Now if the functions of the Spleen,—putting aside the safety-valve action of its distensible cavities,—be the same with that of the lymphatic glands in general, it is easy to understand how its loss may be at once compensated by an increased action on their part, and how it may be permanently replaced by an increased development of certain of those bodies.—Thus, then, we may fairly regard the Spleen as concurring with the glands of the absorbent system, in the assimilating process, by which the crude nutritive materials are rendered fit to circulate in the blood; and as the latter operate upon those which are taken up by the lacteals, so may the former exert their influence upon those, which have been received into the veins,—separating them from the mass of the blood, and delivering them to the lymphatics to be further elaborated.

509. It is worthy of remark, that a Spleen is found in *all* Vertebrated animals, which have a distinct Absorbent system; but that no organ exactly corresponding with it exists in the Invertebrata, which are destitute of that system,—although the distensible cellated cavities, apparently destined to perform its safety-valve function, exist in some of the higher among them. This is an additional reason for regarding its parenchymatous portion as essentially a part of the assimilating apparatus of the Absorbent system.

510. The *Supra-Renal Capsules* seem to correspond with the Spleen in their general structure, and in their connection with the Lymphatic system; whilst in the arrangement of their component parts, they bear more resemblance to the Kidney. Their exterior or cortical portion is formed of straight arteries, which divide into a minute capillary network; and from this arise venous branches, which form a minute plexus, pouring its contents into a large central cavity, which is the dilated commencement of the supra-renal vein. No apparatus of secreting tubes or vesicles can be detected in it; but the interspaces of the venous plexus are filled up with a sort of pulp consisting of minute spherules, averaging about 1-10,000th of an inch in diameter, but varying from nearly twice that size to less than half. These bodies appear to be the *nuclei* of cells, the full development of which is checked; but in the Ruminant animals, and occasionally in the Human subject, the cells are more or less developed, and then resemble the ordinary lymph-corpuscles in size and appearance. The Lymphatics are of large size, like those of the Spleen; and probably convey away the matter which has been elaborated by these organs, that it may be mingled with that which is being taken up and prepared by other parts of the Absorbent system. The Supra-Renal capsules attain a very large size early in fœtal life, surpassing the true Kidneys in dimension, up to the tenth or twelfth week; but they afterwards diminish relatively to the latter, and are evidently subor-

dinate organs, during the whole remainder of life. It does not seem unlikely that these bodies, like the Spleen, have a double function; and that, besides participating in the general actions of the Absorbent glandulæ, they may serve as a diverticulum for the Renal circulation, when from any cause the secreting function of the Kidneys is retarded or checked, and the movement of blood through them is stagnated.

511. The *Thymus Gland* is another body, which seems referable to the same group; having all the essential characters of a true gland (§ 714), save an excretory duct; and its function being evidently connected, during the early period of life at least, with the elaboration of nutritive matter, which is to be re-introduced into the circulating current. Its elementary structure may be best understood from the simple form it presents, when it is first capable of being distinguished in the embryo. It then consists of a single tube, closed at *both* ends, and filled with granular matter; and its subsequent development consists in the lateral growth of branching off-shoots from this central tubular axis. In its mature state, therefore, it consists of an assemblage of glandular follicles, which are surrounded by a plexus of blood-vessels; and these follicles all communicate with the central reservoir, from which, however, there is no outlet. The cavities of the follicles contain a fluid, in which a number of corpuscles are found, giving it a granular appearance. These corpuscles are for the most part in the condition of *nuclei;* but fully developed cells are found among them, at the period when the function of this body seems most active. The chemical nature of the contents at this period, closely resembles that of the ordinary proteine-compounds.—It has been commonly stated, that the Thymus attains its greatest development, in relation to the rest of the body, during the latter part of fœtal life; and it has been considered as an organ peculiarly connected with the embryonic condition. But this is a mistake; for the greatest activity in the growth of this organ manifests itself, in the Human infant, soon after birth; and it is then, too, that its functional energy seems the greatest. This rapid state of growth, however, soon subsides into one of less activity, which merely serves to keep up its proportion to the rest of the body; and its increase usually ceases altogether at the age of about two years. From that time, during a variable number of years, it remains stationary in point of size; but, if the individual be adequately nourished, it gradually assumes the character of a mass of fat, by the development of the corpuscles of its interior into fat-cells, which secrete adipose matter from the blood. This change in its function is most remarkable in hybernating Mammals; in which the development of the organ continues, even in an increasing ratio, until the animal reaches adult age, when it includes a large quantity of fatty matter. The same is the case, generally speaking, among Reptiles. It is an important fact in the history of this organ, that it is not to be detected in Fishes; and does not appear to exist, either in the tadpole state of the Batrachian reptiles, or in the

Perennibranchiate group; so that we may regard it as essentially connected with pulmonic respiration.*

512. Various facts lead to the conclusion, that the function of the Thymus, at the period of its highest development, is that of elaborating and storing up nutritive materials, to supply the demand which is peculiarly active during the early period of extra-uterine life. The elaborating action probably corresponds with that, which is exerted by the glands of the Absorbent system; and the product, as in the preceding cases, seems to be conveyed away by the lymphatics. The provision of a store of nutritive matter seems a most valuable one, under the circumstances in which it is met with; the waste being more rapid and variable than in adults, and the supply not constant. Thus it has been noticed that, in over-driven lambs, the thymus soon shrinks remarkably; but that it becomes as quickly distended again during rest and plentiful nourishment. As the demand becomes less energetic, and as the supplies furnished by other organs become more adequate to meet it, the Thymus diminishes in size, and no longer performs the same function. It then obviously serves to provide a store of material, not for the nutrition of the body, but for the respiratory process, when this has to be carried on for long periods—as in hybernating Mammals and in Reptiles—without a fresh supply of food.—It is possible that the Thymus gland may further stand in the same relation to the Lungs, as the Spleen to the Liver, and the Supra-Renal capsules to the Kidneys; that is, as a *diverticulum* for the blood transmitted through the bronchial arteries (which are the nutritive vessels of the Lungs), before the Lungs acquire their full development in comparison with other organs, or when any cause subsequently obstructs the circulation through their capillaries.

513. The *Thyroid* Gland bears a general analogy to the Thymus; but its vesicles are distinct from each other, and do not communicate with any common reservoir. They are surrounded, like the vesicles of the true glands, with a minute capillary plexus; and in the fluid they contain, numerous corpuscles are found suspended, which appear to be cell-nuclei, in a state of more or less advanced development. This body is supplied with arteries of considerable size; and with peculiarly large lymphatics. Though proportionably larger in the fœtus than in the adult, it remains of considerable size during the whole of life. It appears, from the recent inquiries of Mr. Simon,† that a Thyroid gland, or some organ representing it in place and office, exists in all Vertebrated animals. It presents its simplest form in the class of Fishes; in some of which it appears to consist merely of a plexus of capillary vessels, connected with the origin of the cerebral vessels, and capable, by its distensibility, of relieving the latter, in case of any obstruction to the proper movement of blood through them. In the higher forms of this organ, the glandular structure,—consisting of the closed vesicles over which the capillary

* See Mr. Simon's admirable Prize Essay on the Thymus Gland.

† Philosophical Transactions, 1844.

plexus is distributed, and of their cellular contents,—is superadded: and the organ then appears, like the Spleen, to be destined for two different uses; namely, to serve as a *diverticulum* to the Cerebral circulation; and to aid in the elaboration of nutritive matter, which is taken up by the Absorbent system, and which is again poured by it into the general current of the circulation.

514. Thus the Spleen, the Supra-Renal Capsules, the Thymus Gland, and the Thyroid Gland, all seem to share in the preparation of the nutritive materials of the blood, along with the ordinary glandulæ of the Absorbent system. In fact, we may regard them all as together constituting an apparatus, which is precisely analogous to that of the ordinary glands, but of which the elementary parts are scattered through the body, instead of being collected into one compact structure. Thus if we could imagine any tubular gland, such as the Kidney or the Testis, to be unraveled, and its convoluted tubuli to be spread through the system, yet all discharging their contents by a common outlet, we should have no unapt representation of the Lymphatic portion of the Absorbent system. Its function appears to be, to separate the crude Albuminous matter from the blood, to subject it to an elaborating action performed by the epithelium-cells lining the tubes, and then to pour forth this elaborated product,—not as an excretion to be carried out of the body,—but (in conjunction with that, which has been newly taken in by the Lacteal portion of the system, and which has undergone elaboration by *its* glandulæ), into the blood-vessels, which are to convey it to the different parts of the body where it is to be appropriated. The four bodies we have been just considering, appear to be, so far as their glandular function is concerned, appendages to this system. Their uses as *diverticula* to the circulation through other organs, render them liable to occasional distension with blood; and it seems determined that this blood shall not lie useless, but shall be subservient to the action in question; the gland-cells that line the cavities of the organ withdrawing certain constituents of the blood, to restore them, through the Lymphatic system, in a state of more complete preparation for the operations of Nutrition. Their function is very probably *vicarious;* that is, the determination of blood is greatest (through the state of the other organs) at one time to one of these bodies, and at another time to another. Hence the effects of the loss of any one of them are not serious; as the others are enabled in great degree to discharge its duty.

4. *Composition and properties of the Chyle and Lymph.*

515. The chief chemical difference between the Chyle and the Lymph, consists in the much smaller proportion of solid matter in the latter, and in the almost entire absence of fat, which is an important constituent of the former. This is well shown in the following comparative analyses, performed by Dr. G. O. Rees, of the fluids obtained

from the lacteal and lymphatic vessels of a donkey, previously to their entrance into the thoracic duct; the animal having had a full meal seven hours before its death.

	Chyle.	Lymph.
Water - - - - -	90·237	95·536
Albuminous matter (coagulable by heat)	3·516	1·200
Fibrinous matter (spontaneously coagulable)	0·370	0·120
Animal extractive matter, soluble in water and alcohol - - -	0·332	0·240
Animal extractive matter, soluble in water only - - - - -	1·233	1·319
Fatty matter - - - -	3·601	a trace.
Salts;—Alkaline chloride, sulphate and carbonate, with traces of alkaline phosphate, oxide of iron - - -	0·711	0·585
	100·000	100·000

The Lymph obtained from the neck of a horse has been recently analyzed by Nasse, with nearly the same result. He found it to contain 95 per cent. of water; and the 5 per cent. of solid matter was chiefly composed of albumen and fibrin, with watery extractive,—scarcely a trace of fat being to be found. The proportions of saline matter were found to be remarkably coincident with those, which exist in the serum of the blood; as might be expected from the fact, that the fluid portion of the lymph must have its origin in that which has transuded through the blood-vessels: the absolute quantity, however, is rather less.—A similar analysis of the Chyle of a cat by Nasse, has given results very closely correspondent with that of Dr. Rees; for the proportion of water was 90·5 per cent.; and of the 9·5 parts of solid matter, the albumen, fibrin, and extractive amounted to more than 5, and the fat to more than 3 parts.—Dr. Rees has also analyzed the fluid of the Thoracic duct of Man; which consists of chyle with an admixture of lymph; and he found this to contain about 90·5 per cent. of water, 7 parts of albumen and fibrin, 1 part of aqueous alcoholic extractive, and not quite 1 part of fatty matter with about $\frac{1}{2}$ per cent. of salines. The composition of this fluid more resembles that of the lymph than that of the chyle; the proportion of the fatty to the albuminous matter being small. This was probably due to the circumstance, that the subject from which it was obtained (an executed criminal) had eaten but little for some hours before his death.

516. The characters of the Chyle are not the same in every part of the Lacteal system; for the fluid undergoes a very important series of changes in its characters, in its transit from the walls of the intestines to the receptaculum chyli. The fluid drawn from the lacteals that traverse the intestinal walls, has no power of spontaneous coagulation; whence we may infer that it contains little or no Fibrin. It contains Albumen in a state of complete solution, as we may ascer-

tain by the influence of heat or acids in producing coagulation. And it includes a quantity of fatty matter, which is not dissolved, but suspended in the form of globules of variable size. The quantity of this evidently varies with the character of the food; it is more abundant, for instance, in the chyle of Man and the Carnivora, than in that of the Herbivora. It is generally supposed that the milky colour of the chyle is owing to the oil-globules; but Mr. Gulliver has pointed out that it is really due to an immense multitude of far more minute particles, which he has described under the name of the *molecular base* of the chyle. These molecules are most abundant in rich, milky, opaque chyle; whilst in poorer chyle, which is semi-transparent, the particles float separately, and often exhibit the vivid motions common to the most minute molecules of various substances. Such is their minuteness, that, even with the best instruments, it is impossible to determine either their form or their dimensions with exactness; they seem, however, to be generally spherical; and their diameter may be estimated at between 1-36,000th and 1-24,000th of an inch. Their chemical nature is as yet uncertain; they are remarkable for their unchangeableness, when submitted to the action of numerous re-agents, which quickly affect the proper Chyle-corpuscles; whilst their ready solubility in Ether would seem to indicate that they are of an oily or fatty nature.

517. The milky aspect which the serum of blood sometimes exhibits, is due to an admixture of this molecular base. It may be particularly noticed, when blood is drawn a few hours after a full meal, that has been preceded by a long fast. By recent experiments it has been found, that the serum begins to show this turbidity, about half an hour after the meal has been taken; and that the turbidity increases for some hours subsequently, after which it disappears. The period at which the discoloration is greatest, and the length of time during which it continues, vary according to the digestibility of the food. When the serum is allowed to remain at rest, the opaque matter rises to the surface, presenting very much the appearance of cream; and when separately examined, it has been found to contain a proteine-compound, mingled with oily matter,—the relative amount of the two appearing to depend in part upon the characters of the food ingested. Hence it would not seem improbable, that the molecular base of the chyle is partly derived from albuminous matter of the food, which has not been completely dissolved in the digestive process, but which has been reduced to a state of exceedingly minute division (§ 473). The gradual disappearance of the turbidity of the serum indicates that the substance which occasioned it no longer exists as such in the circulating current; being either drawn off by the nutritive or secretory operations, or being converted by the assimilating process into the ordinary constituents of the blood.

518. During the passage of the Chyle along the lacteals, towards the Mesenteric glands, it undergoes two important changes; the presence of Fibrin begins to manifest itself by the spontaneous coagula-

bility of the fluid; and the oil-globules diminish in proportional amount. The fibrin appears to be formed at the expense of the albumen; as this latter ingredient undergoes a slight diminution. It is in the chyle drawn from the neighbourhood of the mesenteric glands, that we first meet with the peculiar floating cells or chyle-corpuscles, formerly adverted to (§ 212), in any number. The average diameter of these is about 1-4600th of an inch; but they vary from about 1-700th to 1-2600th,—that is, from a diameter about half that of the human blood-corpuscles, to a size about a third larger. This variation probably depends in great part upon the period of their growth. They are usually minutely granulated on the surface, seldom exhibiting any regular nuclei, even when treated with acetic acid; but three or four central particles may sometimes be distinguished in the larger ones. These corpuscles are particularly abundant in the chyle obtained by puncturing the mesenteric glands themselves; and there can be little doubt, that they are identical with the altered epithelium-cells, which line the lacteal tubes in their course through those bodies (§ 496).

519. The glandular character of these cells, and their continued presence in the circulating fluid, seem to indicate that they have an important concern in the process of Assimilation,—that is, in the conversion of the crude elements derived from the food, into the organizable matter adapted to the nutrition of the body; in other words, in the conversion of Albumen into Fibrin; which change would seem to take place to a considerable extent in the Mesenteric glands. For it is only in the Chyle which is drawn from the lacteals intervening between the mesenteric glands and the receptaculum chyli, that the spontaneous coagulability of the fluid is so complete as to produce a perfect separation into *clot* and *serum*. The former is a consistent mass, which, when examined with the microscope, is found to include many of the chyle-corpuscles, each of them being surrounded with a delicate film of oil; the latter bears a close resemblance to the serum of the blood, but has some of the chyle-corpuscles suspended in it. Considerable differences present themselves, however, both in the perfection of the coagulation, and in its duration. Sometimes the chyle sets into a jelly-like mass; which, without any separation into coagulum and serum, liquefies again at the end of half an hour, and remains in this state. The coagulation is usually most complete in the fluid drawn from the receptaculum chyli and thoracic duct; and here the resemblance between the floating cells, and the white or colourless corpuscles of the blood, becomes very striking.

520. The Lymph, or fluid of the Lymphatics, differs from the Chyle, as already remarked, in its comparative transparency: its want of the opacity or opalescence, which is characteristic of the latter, being due to the absence, not merely of oil-globules, but also of the "molecular base." It contains floating cells, which bear a close resemblance to those of the Chyle on the one hand, and to the colourless corpuscles of the Blood on the other; and these, as in the preceding case, are most numerous in the fluid, which is drawn from

the lymphatics that have passed through the glands, and in that obtained from the glands themselves. Lymph coagulates like chyle; a colourless clot being formed, which encloses the greater part of the corpuscles. The Lacteals may be regarded as the Lymphatics of the intestinal walls and mesentery; performing the function of interstitial absorption, as well as effecting the introduction of alimentary substances from without. During the intervals of digestion, they contain a fluid, which is in all respects conformable to the lymph of the lymphatic trunks.

521. Thus by the admixture of the aliment newly introduced from without, with the matter which has been taken up in the various parts of the system, and by the preparation which these undergo in their course towards the thoracic duct, a fluid is prepared, which bears a strong resemblance to blood in every particular, save the presence of *red* corpuscles. Even these may sometimes be found in the contents of the thoracic duct, in sufficient amount to communicate to them a perceptible red tinge; but there can be little doubt that they have found their way thither accidentally,—some of the lymphatic or lacteal trunks, which have been divided in the dissection necessary to expose the duct, having taken up blood by their open mouths, and rapidly transmitted it into the general receptacle. The fluid of the thoracic duct may be compared to the blood of Invertebrated animals; from which the red corpuscles are almost or altogether absent; but which contains white or colourless corpuscles, and which possesses but a slight coagulating power, in consequence of its small proportion of fibrin. And we hence see, why these animals should require no *special* absorbent system; since the blood-vessels convey a fluid, which is itself so analogous to the chyle and lymph to be absorbed, that the latter may be at once introduced into it, without injuring its qualities.

5. *Absorption from the External and Pulmonary Surface.*

522. Although the Mucous Membrane of the Alimentary Canal is the *special* channel for the introduction of nutritive or other substances into the system, it is by no means the *only* one. The Skin covering the body, and the Mucous Membrane prolonged into the Lungs, are also capable of absorbing liquids and vapours, and of introducing them into the Circulation; although they serve this purpose less in Man and the higher animals, than in some of the lower. Their utility in this respect is best shown, when, from peculiar circumstances, the function of the digestive cavity cannot be properly performed; and when, therefore, the system has been more than usually drained of its fluids, and stands in need of a fresh supply.—Thus shipwrecked sailors, and others, who are suffering from thirst, owing to the want of fresh water, find it greatly alleviated, or altogether relieved, by dipping their clothes into the sea, and putting them on whilst still wet, or by frequently immersing their own

bodies. In a case of dysphagia, in which neither solid nor fluid nutriment could be introduced into the stomach, the patient was kept alive for a considerable time, and his sufferings greatly alleviated, by the administration of nutritive clysters, and by the immersion of his body in a bath of tepid milk and water, night and morning. Under this system, the weight of the body, which had previously been rapidly diminishing, remained stationary, although the amount of the excretions was increased; and the use of the bath had a special influence in assuaging the thirst, which was previously distressing. It appeared that the water of the urinary excretion, amounting to from 24 oz. to 36 oz. per day, must have been entirely supplied from this latter source. Again, a man who had lost nearly 3 lbs. by perspiration, during an hour and a quarter's labour in a very hot atmosphere, regained 8 oz. by immersion in a warm bath at 95° for half an hour.—In these cases it appears probable, from the experiments already noticed (§ 502), that the Lymphatics, rather than the blood-vessels, are the chief agents in the absorbing process; not, however, from any powers peculiar to them, but merely on account of the thinness of their walls, and their very copious distribution in the skin.

523. Absorption may also take place from an atmosphere saturated with watery vapour. Of this we have a very curious proof in the Frog; whose urinary bladder (which serves as a sort of reservoir of water) has been observed to be refilled, after having been emptied, by placing the animal in an atmosphere loaded with watery vapour. Numerous instances are on record, which prove that such absorption may take place in Man, to a very considerable extent; though the proportion introduced through the Skin, and through the Lungs, cannot be exactly ascertained. The ready introduction of volatile matter into the system, through the latter channel, is a matter of familiar experience; thus if we breathe an atmosphere through which the vapour of turpentine is diffused, it soon produces the characteristic odour of violets in the urinary secretion. And it is probably in this manner, that a large number of those poisonous miasmata are introduced, which are such fertile causes of disease.

6. *Of the Composition and Properties of the Blood.*

524. Having traced the steps by which the blood is elaborated, and prepared for circulation through the body, and having (in the former part of the volume) inquired into the characters of its chief constituents, we have now to consider the fluid as a whole, to study the usual proportions of these constituents, and the properties which they impart to it.

525. The Blood, whilst circulating in the living vessels, may be seen to consist of a transparent, nearly colourless fluid, termed *liquor sanguinis;* in which the *corpuscles*, to which the blood owes its *red* hue, as well as the white or *colourless* corpuscles, are freely suspended

and carried along by the current.—On the other hand, when the blood has been drawn from the body, and is allowed to remain at rest, a spontaneous coagulation takes place, separating it into clot and serum. The clot is composed of a network of *Fibrin*, in the meshes of which the *Corpuscles*, both red and colourless, are involved; and the serum is the same with the liquor sanguinis deprived of its Fibrin. When the Serum is heated, it coagulates, showing the presence of *Albumen.* And if it be exposed to a high temperature, sufficient to decompose the animal matter, a considerable amount of earthy and alkaline *salts* remains.—Thus we have four principal components in the Blood;—namely, Fibrin, Albumen, Corpuscles, and Saline matter. In the *circulating* Blood they are thus combined:—

Fibrin Albumen Salts	In solution, forming Liquor Sanguinis.
Red Corpuscles,—Suspended in Liquor Sanguinis.	

But in *coagulated* blood they are thus combined:—

Fibrin Red Corpuscles	Crassamentum or Clot.
Albumen Salts	Remaining in solution, forming Serum.

A certain amount of Serum, however, is involved in the Crassamentum; and can only be separated by cutting the clot into thin slices, and carefully washing it.

526. The components of the Blood may be separated, and their amount estimated, in various ways. Thus, if fresh-drawn blood be continually stirred with a stick, or be "whipped," with a bunch of twigs, the Fibrin coagulates in the form of strings, which adhere to the wood, and may thus be withdrawn; whilst the red corpuscles then remain suspended in the serum, gradually sinking to the bottom in virtue of their greater specific gravity.—On the other hand, the Red Corpuscles may be separated, in those animals in which they are large enough, by passing the blood through a filter; having previously mingled with it some substance, which retards, but does not prevent its coagulation* (§ 185). The liquor sanguinis is thus separated from the blood-discs; and the former coagulates, whilst the blood-discs are retained upon the filter. This experiment convincingly proves, that the act of coagulation is not due to the red corpuscles, as was at one time imagined. The ordinary act of coagulation, by withdrawing the Fibrin and Corpuscles, makes it easy to estimate the proportion of Albumen and of Saline matter in the Blood, when due allowance is made for the quantity of Serum retained in the Clot; and the relative proportions of these may be determined, by evaporating the

* This experiment cannot be performed with Human blood, because the corpuscles are small enough to pass through the pores of any filter that allows the liquor sanguinis to permeate it; but it answers very well with Frog's blood.

fluid, so as to obtain the whole amount of solid matter it contains, and by then calcining the residuum, so as to ascertain how much of this is a mineral ash,—the remainder being chiefly Albumen.—The solid matter of the blood also contains various *Fatty* substances, which may be removed from it by ether. Some of these appear to correspond with the constituents of ordinary Fat (§ 261); whilst another contains phosphorus, and seems allied to the peculiar fatty acids of Neurine (§ 383); and another has some of the properties of Cholesterine, the fatty matter of the Bile (§ 724).—Besides these, there are certain substances known under the name of *Extractive;* one group of which is soluble in water and another in Alcohol. Of the precise nature of these, little is known. They have been aptly termed "ill-defined" animal principles; and it is probable that they may include various substances in a state of change or disintegration, which are being eliminated from the Blood by the processes of Excretion.

527. The general result of numerous recent analyses of the Blood may be thus stated:—The whole amount of solid matter is greater in the Male than in the Female. The higher proportion extends to all its components except the Albumen; and this is almost invariably present in an amount, which is *absolutely* greater in 1000 parts of female blood, than in 1000 parts of that of the male, and which is considerably greater in *proportion* to the other solid matters. The proportion of Albumen seems more constant than that of the other constituents of Blood; seldom varying beyond 5 or 6 parts either more or less than 70 in 1000.—The quantity of Corpuscles appears liable to considerably greater variation; the superiority on the side of the Male, however, being very strongly marked in the maximum and minimum, as well as in the average. We may regard its average in the Male at about 140 in 1000 parts of blood; but it may fall to 110·5 parts, without the health being seriously affected; whilst, on the other hand, it may arise to 186 without any manifestation of disease. In the Female, its average may be about 112 parts in 1000; but it may fall to as little as 71·4, and may rise to 167, consistently with ordinary health. The range of variation is thus much greater in the Female than in the Male; the minimum being considerably less in the former, than half the maximum; whilst in the latter, it is much more. This is probably due in part to the fact, that the loss by the Catamenial discharge may produce a great temporary depression in the proportion of the corpuscles.—The average proportion of Fibrin seems to be no more than 2·2 in the Male; and though it may rise to as much as 3·5 or even 4, without disordering the system, it does not seem to fall below 2, in the state of ordinary health. The average in the Female is probably about 2; the proportion may rise to 3, or fall to 1·8; but the variation seems less considerable in the Female than in the Male.—Much is probably yet to be learned, regarding the influence of different kinds of food recently taken, on the proportion of these constituents of the blood; and it does not seem unlikely, from what has been already stated (§ 517), that the quantity of fatty matter

is especially liable to variation, in accordance with the amount contained in the food, and the time which has elapsed since the last meal.

528. The Saline constituents of the blood, obtained by drying and incinerating the whole mass, usually amount to between 6 and 7 parts in 1000. More than half of their total quantity is composed of the Chlorides of Sodium and Potassium; and the remainder is made up of the tribasic Phosphate of Soda, the Phosphates of Lime and Magnesia, Sulphate of Soda, and a little Phosphate and Oxide of Iron. Of these the chief part are dissolved in the Serum; but the Earthy Phosphates, which are insoluble by themselves, are probably combined with the proteine-compounds (§ 175); and the iron is contained, chiefly or entirely, in the red corpuscles. It is difficult to speak with certainty, from the examination of the *ashes* of the blood, as to the state of the saline constituents of the circulating *fluid*. Thus, the Serum has an alkaline reaction; and this has been supposed to be due to the presence of alkaline Carbonates. Moreover, the presence of the Lactates of potash and soda has been usually asserted. On the other hand, some recent analyses would indicate, that the alkaline reaction is entirely due to the presence of the tribasic Phosphate of soda; and that no alkaline carbonates or lactates exist in the blood. This discrepancy seems partly due to the mode of analysis employed; for it has been lately pointed out by Dr. G. O. Rees, that although the ashes of the entire mass of blood do not effervesce on the addition of an acid, effervescence takes place, when acid is added to the ashes of the Serum; showing the existence in it, either of alkaline Carbonates, or of Lactates which have been reduced to the state of Carbonates by incineration. It appears that when the entire mass of blood is incinerated, enough phosphoric acid is produced from the phosphorized fats, to neutralize the alkaline carbonates, and thus to prevent their presence from being recognized. There can be no doubt, however, that the tribasic phosphate of soda exists as such in the blood, and contributes to its alkaline reaction; and it appears to confer upon the serum a special power of absorbing carbonic acid.

529. The following appear, from the considerations stated in the preceding part of the Volume, to be the chief uses of the principal constituents of the Blood, in the general economy. The Fibrin is the material, which is most completely prepared for organization, and which supplies what is requisite for the nutrition of the larger proportion of the solid tissues of the body. It is, therefore, being continually withdrawn from the blood by the nutritive operations; and the demand appears to be supplied, in part by the influx of Fibrin that has been prepared in the Absorbent system, and in part by the continued transformation of Albumen, which takes place during the Circulation of the Blood. If a proper amount of Fibrin be not present in the Blood, its physical properties are so far altered, by the diminution of its viscidity, that it will not circulate through the capillaries as readily as before,—a certain degree of viscidity having been experimentally found to be favourable to the movement of fluid

through glass or metallic tubes of small bore.—The Albumen of the blood is the raw material, at the expense of which not only the Fibrin, but many other substances are generated during the nutritive process. All the Albuminous compounds of the Secretions, the Horny matter of the Epidermic tissues, the Gelatin of the simple fibrous tissues, the solid materials of the Red Corpuscles, and other substances, may be regarded as almost certainly produced by the transformation of the Albumen of the Blood; and a continual supply of this from the food is therefore requisite, to preserve the due proportion in the circulating fluid.—The Red Corpuscles, which (it will be remembered) are almost exclusively confined to Vertebrated animals, appear to be more connected with the function of Respiration, than with that of Nutrition; and the stimulating action of Arterial blood, especially upon the Muscular and Nervous tissues, appears chiefly to depend upon their presence. It has been observed in particular, that their presence is more effectual in stimulating the heart's action, than is that of either of the other constituents of the blood. In addition to what has been already stated (§ 219), in reference to their continual disintegration and renewal, it may be mentioned, that when the blood of one animal was injected by Majendie into the veins of another having discs of very different size and form, the original Red corpuscles soon disappeared, and were replaced by those characteristic of the species, in whose veins the fluid was circulating.

530. The use of the Saline matter is evidently in part to prevent decomposition in the circulating Blood; but also to supply the mineral materials, requisite for the generation of the tissues, and entering into the composition of the secretions. It is by the saline and albuminous matters in conjunction, that the specific gravity of the Liquor Sanguinis is kept up to the point, at which it is equivalent to that of the contents of the Red Corpuscles; and it is only in this condition, that the formation of the latter can duly take place.—The Fatty matters of the Blood are evidently derived from the food, either directly, or by a transformation of its farinaceous ingredients (§ 430); and they are chiefly appropriated to the maintenance of the combustive process. That which may be superfluous is either deposited in the cells of Adipose Tissue, or it is eliminated by the Liver, the Sebaceous follicles of the Skin, and, in the female when nursing, by the Mammary glands. The blood appears to contain, ready formed, the peculiar azotized and phosphorized fat of Nervous matter; but how this is generated,—whether by the combination of azotized and phosphorized ingredients with ordinary fat, or by the metamorphosis of albuminous matter,—cannot be said to be yet determined.

531. The proportion of these components of the Blood is liable to undergo changes in disease, which extend far beyond the widest limits which have been mentioned as consistent with health. Thus, the quantity of Fibrin exhibits a remarkable *increase* in Inflammation; the amount then found in the blood being from 5 or 6 parts in 1000

to 9, 10, or even $10\frac{1}{2}$, according to the extent and intensity of the disease. On the other hand, it presents a remarkable *diminution* in Typhoid fevers; the quantity being sometimes as little as 0·9. If any decided Inflammation should develop itself, however, in the course of the Fever, the proportion of Fibrin rises accordingly. A deficiency of Fibrin in the blood predisposes to Hemorrhages, Congestions, &c., either into the substance of the tissues, or on the surface of membranes; and these conditions are well known to be of frequent occurrence as complications of febrile disorders. An excess of Fibrin is not much affected by copious bleeding, even if this be frequently repeated; but there is reason to think, that the administration of Mercury has a tendency to restrain its production.

532. It is difficult to say what amount of Red Corpuscles should be regarded as excessive; since, as we have seen, they may augment to a great degree, without disturbing the health. When they are present in an amount much above the average, they seem concerned in producing the condition termed Plethora; which marks a "high condition" of the system, and which borders upon various diseases, especially those of Congestion, and Hemorrhages. To these a peculiar liability then exists; because, although the proportion of Fibrin in the blood is not absolutely low, it is low in reference to that of the Red Corpuscles. Plethoric persons do not seem more liable to Inflammation, than are those of weakly constitution. The quantity of the Red Corpuscles is rapidly diminished by frequent bleeding; and hence it is lowered by repeated Hemorrhages. On the other hand, it is speedily restored to its usual standard under the influence of nutritious diet, if the digestive powers have not been too much weakened to make use of this.—The proportion of Red Corpuscles undergoes a marked diminution in various forms of Anæmia; and particularly in Chlorosis. In severe cases of this latter disease, it has been found as low as 27 in 1000; and it not unfrequently sinks to 40 or 50. The marked influence of the administration of Iron, in favouring the reproduction of Red Corpuscles, has been already noticed (§ 219).

533. The proportion of Albumen in the Blood seems less liable to change, except in the condition termed Albuminuria, in which a large quantity of Albumen appears in the Urine. When this condition is permanently established, it is indicative of the existence of serious organic disease of the kidney; but it may occur for a short time under the influence of simple congestion of that organ, which causes an escape of the albuminous part of the blood, together with the water which is filtered-off (as it were) in this gland (§ 728). Now when Albuminuria is fully established, there is a marked diminution in the quantity of Albumen in the serum of the blood; and this diminution is constantly proportional to the amount of Albumen present in the Urine. The proportion of Saline matter appears to undergo less alteration in disease than that of the other constituents of the Blood; and has not been found to have a regular correspondence, either in the way of excess or diminution, with any particular morbid state.

534. The condition of the Blood may be affected, not merely by alteration in the proportions of its normal ingredients, but by the presence of other substances;—either such as are generated in it, and are constantly being eliminated from it in health, but have accumulated to an abnormal degree;—or such as have found their way into it from without. Thus, Carbonic Acid, Urea and Lithic Acid, Cholesterine and other elements of Bile, and other matters which it is the office of the Excreting organs to remove, may accumulate in the blood, and may become fertile sources of disease, by their injurious influence. The introduction of various Mineral substances, by absorption from without, changes the composition of the normal elements of the Blood, and thus affects their vital properties; thus strong saline solutions diminish or destroy the coagulating power of the Fibrin. But the most remarkable cases of depravation of the Blood, by the introduction of matters from without, are those which result from the action of *ferments*,—exciting such Chemical changes in the constitution of the fluid, that its whole character is speedily changed, and its vital properties are altogether destroyed. Of such an occurrence we have a marked example in the various forms of malignant fevers; in which the introduction of a very minute quantity of noxious matter into the blood, either through the lungs or through the skin, produces a speedy alteration in the characters of the whole mass of the blood, the function of every organ in the body is disordered, and decomposition of the solids and fluids takes place to a considerable extent, even before circulation ceases, and whilst consciousness yet remains. The train of symptoms produced by the bite of venomous Serpents, and of rabid animals, appears referable to the same cause,—the alteration in the condition of the whole current of blood, by the introduction of a minute quantity of a substance that acts as a ferment.

535. The Coagulation of the Blood, as already explained, depends upon the passage of its Fibrin from the fluid state to the solid (§ 184); consequently, if the fibrin be separated from the other elements, no coagulation takes place. On the other hand, if the amount of Fibrin be larger than ordinary, the coagulum possesses an unusual degree of firmness. The length of time which elapses before coagulation, and the degree in which the Clot solidifies, vary considerably; in general they are in the inverse proportion to each other. Thus, if a large quantity of blood be withdrawn from the vessels of an animal at the same time, or within short intervals, the portions that last flow coagulate much more rapidly, but much less firmly, than those first obtained, in consequence of the diminished proportion of fibrin. On the other hand, when the fibrin is in excess, its coagulation is unusually delayed. From this delay an important change results, in the mode in which the coagulation takes place; for the red corpuscles, instead of being uniformly diffused through the coagulum, have time to sink to the bottom, in virtue of their greater specific gravity; and the upper part of the clot is consequently made up of Fibrin, almost exclusively, whilst the lower is chiefly formed by the aggre-

gation of the red corpuscles. Hence the upper layer is almost destitute of colour, (whence it has received the name of *buffy coat*,) and is remarkably tenacious in its character; whilst the lower is very deep in hue, and very friable in consistence. When the fibrillated network forming the buffy coat undergoes the slow contraction, which is characteristic of highly-elaborated fibrin subsequently to its coagulation, it draws in the edges of the upper surface of the clot, giving it a *cupped* appearance.

536. The Buffy Coat may present itself under a great variety of conditions; and it can no longer, therefore, be regarded as it formerly was, a sign of the Inflammatory state. It is most fully developed when acute Inflammation exists; because in that condition *all* the circumstances which favour it are present. That it may be produced by any cause, which occasions delay in the coagulation of the blood, is evident from the fact, that healthy blood may be made to exhibit it, by adding a solution of a neutral salt, which retards, but does not prevent its coagulation. But the blood may coagulate with its ordinary rapidity, or even more speedily than usual; and may yet exhibit the Buffy Coat. And, moreover, the separation of the Fibrin and the Red Corpuscles may take place in films of blood so thin, as not to admit of a stratum of one being laid over the other; the two elements separating from each other laterally, and the films acquiring a speckled or mottled appearance, equally characteristic of the Inflammatory condition with the Buffy coat itself. Hence the separation must be due in such cases to other causes than gravity, and recent observations have accounted for it, by showing that the Red Corpuscles have an unusual attraction for one another in the Inflammatory state, causing their coalescence in piles and masses; whilst the particles of Fibrin have also a peculiarly strong attraction for each other. Thus there is a powerful tendency, that draws together the components of each kind, and consequently tends to separate them from the others; and when this separation takes place, the difference in the specific gravity of the two elements decides their respective situations.—The peculiar tendency of the Red corpuscles to unite, in the Inflammatory state, serves to distinguish this condition, even in a single drop of blood; and it is then that the White corpuscles may be most easily distinguished, as

Fig. 82.

The microscopic appearance of a drop of blood in the inflammatory condition. The *red* corpuscles lose their circular form, and adhere together; the *white* corpuscles remain apart, and are more abundant than usual.

they are seen apart from the rest of the mass, having no tendency to unite with it. In fact, the white corpuscles are not found in company with the red, in the ordinary coagulum, but rather with the fibrinous portion; and when they are peculiarly abundant, as they usually are in Inflammatory blood, they may form a considerable proportion of the buffy coat.

537. The Buffy Coat may present itself, without the least increase in the normal quantity of Fibrin, and without any approach to the Inflammatory state; simply because the Fibrin is present in excessive amount, in relation to the amount of Red corpuscles, the latter being much below their usual proportion. Thus in severe Chlorosis, the buffy coat is almost as strongly marked as in the severest Inflammation; but the two conditions are at once distinguished by the relative proportions of solid matter in the blood, as indicated by the size of the Coagulum. For in Chlorosis the coagulum is very small, in consequence of the reduced proportion of Corpuscles, and is almost invariably found floating in the serum; whilst in the ordinary Inflammatory condition, it is of full size, frequently adhering to the side of the vessel.

CHAPTER VI.

OF THE CIRCULATION OF THE BLOOD.

1. *Nature and Objects of the Circulation of Nutrient Fluid.*

538. The nutritive fluid,—the elements of which are thus chiefly taken up by the Absorbent system, and are there prepared, as by glandular apparatus diffused through the whole body, to be mingled with the general mass of the previously-formed Blood,—is carried into the various parts of the system, by the act of Circulation. This movement answers various purposes. It furnishes all the tissues, which are to derive nutriment from the Blood, with a constantly renewed supply of the materials which they severally require; and in this manner it is subservient to the growth, not only of those tissues which form part of the solid structure of the body, but also of those various cells, covering its free surfaces, which are being continually cast off and renewed, and which, in the course of their development, separate from the blood the products that are to perform ulterior purposes in the economy, or are to be cast off as altogether effete. Thus the Circulation is subservient to the functions of Nutrition and Secretion. In the exercise of these functions, different materials are drawn from the blood by the several tissues it supplies. Thus the nutrition of the muscle requires fibrin; that of the nerve requires fatty-matter; that of

the bone draws off gelatin and earthy salts; that of the hepatic cells removes the fatty matter and other elements of bile; that of the milk-cells (during lactation) separates albuminous, fatty, and saccharine substances;—and so on. Thus various portions of the blood, when returning from the several organs through which they have been transmitted, have undergone very different changes by the nutritive and secreting processes, according to the function of the organs which they have supplied; and if the same portion of the circulating fluid were constantly being transmitted to each organ, and returned from it, its composition would speedily undergo a change that would render it no longer fit for its purposes. By the union of the different local circulations, however, into one general circulation, this change is prevented, and the whole mass of the blood is maintained in its normal or regular condition; for as its composition is such, as to supply all parts of the body, in a state of health, with the proportions of nutritive material which they respectively need, and as the returning currents are all mingled together in the vessels, before being again distributed to the system, each part supplies what the other has been deprived of, and thus the normal proportion of ingredients in the whole mass of the blood is constantly kept up, whilst in each of its separate streams it is undergoing an alteration of a different kind.

539. But these processes alone might be carried on by the aid of a much less rapid Circulation, than that which exists in Man and the higher animals. We do, in fact, occasionally meet with examples, in which they continue for some time, under an almost total stagnation of the current. There are others, however, which require a much more rapid and uninterrupted movement of the circulating fluid. We have already seen that, for the *action* of the Nervous and Muscular tissues, *oxygen* is necessary; and the amount of that gas contained in the blood circulating through these tissues would be very speedily exhausted, if it were not continually renewed; whilst the carbonic acid, which is formed at the expense of that oxygen, would speedily accumulate to an injurious degree, if it were not carried off as fast as it is produced. Hence we find that in all Animals, the maintenance of the Respiration, by carrying Oxygen from the respiratory surface into the different parts of the system, and by conveying back Carbonic acid to be thrown off at the Respiratory surface, is one of the great purposes of the Circulation of the blood; and its extreme importance is shown by the very speedy check, which the interruption of this function produces in the movement of the blood, in warm-blooded animals. Thus in a Bird or Mammal, completely cut off from Oxygen, the circulation in the lungs will come to a stop, which stoppage will necessarily extend itself over the whole body, in little more than three minutes. We find, then, that the rate of the Circulation in different animals, bears a relation to the energy of their Respiration; and this energy is closely connected with the general activity of their functions, but particularly with that of the Nervous and Muscular systems, which are most dependent for the exercise of their powers,

upon a continually fresh supply of oxygen, and upon the unceasing removal of the carbonic acid which is generated in their substance.

2. *Different forms of the Circulating Apparatus.*

540. It is desirable that the Circulating apparatus should be first studied in its very simplest form,—that which it possesses in Plants and in the lowest tribes of Animals; as in this way alone can the forces, which are concerned in the movement of the fluid, be rightly appreciated. There are, in all the higher Plants, two distinct currents, that of the *ascending*, and that of the *descending* sap. The former of these fluids should be compared rather with the chyle than with the blood of Animals; for it is a crude fluid, not yet prepared to take part in the nutrition and extension of the structure. But there are some circumstances attending its movement, which throw light upon other more complicated phenomena. The ascending sap consists principally of water; which is imbibed, together with various substances which it holds in solution, by the delicate tissue at the soft extremities of the root-fibres, or spongioles. The power of forcing upwards a column of sap, which exists in these bodies, and which seems due to Endosmose (§ 491), is shown by very simple experiments. If the stem of a Vine, or of any tree in which the sap rises rapidly, be cut across when in full leaf, the sap continues to flow from the lower extremity; and this with such force, as to distend with violence, or even to burst, a bladder tied firmly over the cut surface. If instead of a bladder, a bent tube be attached to this, and mercury be poured into it so as to indicate the pressure exerted, it is found that the rise of the sap takes place with a force equal to the pressure of from one to three atmospheres (from 15 to 45 lbs. upon the square inch)—or even more. Thus the ascent of the sap is partly due to a powerful *vis a tergo*, or impelling influence, derived from the point where the absorption takes place.

541. But, on the other hand, if the upper extremity be placed with the cut surface of the stem in water, a continued absorption of that fluid will take place, as is evidenced by the withdrawal of the water from the vessel; the fluid which is thus taken up, however, is not retained within the stem and branches, but is carried into the leaves, and is thence dissipated by exhalation. It is obvious, then, that the *vis a tergo* is not the sole cause of the ascent of the sap; but that a *vis a fronte* also exists, by which the fluid is drawn towards the parts in which it is to be employed. This is further made apparent by a few simple experiments. If a branch, when thus actively absorbing fluid, be carried into a dark room, the absorption and ascent of fluid immediately cease almost completely; and are renewed again, so soon as the leaves are again exposed to light. Now we know, from other experiments, that light stimulates the exhaling process (§ 87), whilst darkness checks it; and the cessation of the demand in the leaves thus produces a cessation in the absorption at the lower extremity of

the stem. And this is the case also, in the natural condition of the plant; as is easily shown by immersing the roots in water, and observing the respective quantities which are removed by absorption during sunshine, shade, and darkness. On the other hand, the movement of the sap may be excited, when it would not otherwise take place, by the production of a demand at the extremities of the branches; thus if a branch of a vine growing in the open air, be introduced into a hot-house, and be subjected to artificial heat during winter, its buds will be developed, its leaves will expand, and these will draw fluid to themselves through the roots and stem, which are still inactive as regards the remainder of the tree. And the natural commencement of the movement of the ascending sap, which takes place with the returning warmth of spring, has been experimentally shown to occur, in the first instance, not in the neighbourhood of the roots, but nearest the extremities of the branches; the exhalation of fluid from the expanding buds being the first process, and a demand for fluid being thus created, which is supplied by the flow that is thus excited in the lower part of the stem,—this, again, being supplied from the roots, which are thus caused to recommence their absorbent function.

542. Thus we see that, in the ascending sap, the movement is entirely regulated by the demand for fluid, occasioned by the actions of the leaves; even though it is in great part dependent on the *vis a tergo*, which has its seat in the spongioles. Not even this force, however, —powerful as it has been shown to be,—can produce the continuance of the upward flow, when the exhalation from the leaves is checked by darkness, and when the demand occasioned by the action of these organs is consequently suspended.

543. The movement of the descending sap offers numerous points, which deserve to be carefully considered. This fluid is strictly comparable to the blood of animals; having undergone a preparation or elaboration in the leaves, which adapts it to the nutrition and extension of the structure, and to the formation of the various secretions of the plant. A great part of the fluid of the ascending sap has been lost by exhalation; and the remainder, thus concentrated, receives a large additional supply of solid matter through the agency of the green cells of the leafy parts, which take in carbon from the atmosphere (§ 83); so that it now includes a considerable amount of gummy matter, in the state prepared for being converted into solid tissue; as well as numerous other compounds. Now this elaborated sap is then conveyed into the various parts of the system, through the agency of a network of vessels, which takes its origin in the leaves, and extends along the branches to the stem and roots, chiefly in the bark of those parts. These vessels are strictly analogous to the *capillaries* or smallest blood-vessels of Animals; but they differ from them in this,— that the capillary network of Animals communicates on either side with larger trunks, being formed, in fact, by the interlacement or anastomosis of their minutest branches,—whilst the network of nutri-

tive vessels in Plants is everywhere continuous with itself, not having any communication with large vessels, so that the fluid prepared in the leaves commences a circulation there, which is continued on the same plan, until it has found its way to its remote destination in the roots.

544. The natural movement of the elaborated sap through these vessels may be studied, under favourable circumstances, with the assistance of the microscope; the requisite conditions being, that the part should be sufficiently transparent for the vessels to be distinctly seen, that the sap shall contain globules in sufficient number to allow its movement to be distinguished by their means, and that the circulation should be observed without the separation of the organ examined from the rest of the Plant, which would produce irregular movements, by the escape of the sap from the wounded part. These conditions may be attained in many Plants;—most conveniently, perhaps, in the stipules of the Ficus elastica, one of the trees which affords the largest supplies of Caoutchouc; and it is then found that the movement takes place in the following manner. Distinct currents are seen, passing along the straightest and most continuous vessels, and crossing by the lateral connecting branches of the network. These currents follow no determinate direction; some proceeding up, and others down; some to the left, and others to the right: not unfrequently a complete stoppage is seen in one or more of the channels, without any obvious obstruction; and the movement then recommences, perhaps, in the opposite direction. The influence of a force, developed by the act of circulation, which determines the direction of the movement, appears from this; that if a tube be cut off, so as to give its contents an equally free exit at both ends, the sap only flows out at one extremity. The movement is retarded by lowering the temperature of the surrounding air, and it is completely checked by extreme cold; it is capable of being renewed by moderate warmth; and a further addition of heat increases its rapidity. By a strong electric shock, the force by which the latex is propelled seems to be altogether destroyed; for the movement then ceases entirely.

545. Now it is quite certain that this circulation cannot be due to any *vis a tergo;* both because it is not constant in its direction in particular vessels; and because there is no organ in which any propelling force, that could extend itself through such a complex system of vessels, may be developed. Nor can it be in any way due to the force of gravity; for although this may assist the descent of the fluid through the stem, it is totally opposed to its ascent from the ends of its branches towards their origin, when, as often happens, the latter are at the higher level. Moreover, it may be noticed that this circulation takes place most readily, in parts that are undergoing a rapid development; and that its energy corresponds with the vitality of the part. Further, it may be observed to continue for some time in parts that have been completely detached from the rest; and on which neither *vis a tergo*, nor *vis a fronte*, can have any influence.

It is evident, then, that the force,—whatever be its nature,—by which this continued movement is kept up, must be developed by the processes to which that movement is subservient; in other words, that the changes involved in the acts of nutrition and secretion are the real source of the motor power. The manner in which they become so, is the next object of our inquiry; and on this subject, some new views have recently been put forth by Prof. Draper, which seem to account well for the phenomena.

546. It is capable of being shown, by experiments on inorganic bodies, that, if two liquids communicate with each other through a capillary tube, for the walls of which they both have an affinity, but this affinity is stronger in the one liquid than in the other, a movement will ensue; the liquid which has the greatest affinity being absorbed most energetically into the tube, and driving the other before it. The same result occurs when the fluid is drawn, not into a single tube, but into a network of tubes, permeating a solid structure; for if this porous structure be previously saturated with the fluid, for which it has the less degree of attraction, this will be driven out and replaced by that for which it has the greater affinity, when it is permitted to absorb this. Now if, in its passage through the porous solid, the liquid undergoes such a change, that its affinity be diminished, it is obvious that, according to the principle just explained, it must be driven out by a fresh supply of the original liquid, and that thus a continual movement in the same direction would be produced.

547. Now this is precisely that which seems to take place in the organized tissue, permeated by nutritious fluid. The particles of this fluid, and the solid matter through which it is distributed, have a certain affinity for each other; which is exercised in the nutritive changes, to which the fluid becomes subservient during the course of its circulation. Certain matters are drawn from it, in one part, for the support and increase of the woody tissue; in another part, the secreting cells demand the materials which are requisite for their growth,—as starch, oil, resin, &c.; and thus in every part that is traversed by the vessels, there are certain affinities between the solids and the fluids, which are continually being newly developed by acts of growth, as fast as those which previously existed are satisfied or neutralized by the changes that have already occurred. Thus in the circulation of the elaborated sap, there is a constant attraction of its particles towards the walls of the vessels, and a continual series of changes produced in the fluid, as the result of that attraction. The fluid, which has given up to a certain tissue some of its materials, no longer has the same attraction for that tissue; and it is consequently driven from it by the superior attraction, then possessed by the tissue for another portion of the fluid, which is ready to undergo the same changes, to be in its turn rejected for a fresh supply. Thus in a growing part, there is a constantly renewed attraction for the nutritive fluid, which has not yet traversed it; whilst, on the other hand, there is a diminished attraction for the fluid, which has yielded up the nu-

tritive materials required by the particular tissues of the part; and thus the former is continually driving the latter before it.

548. But the fluid which is thus repelled from one part, may still be attracted towards another; because that portion of its contents, which the latter requires, may not yet have been removed from it. And in this manner, it would seem, the flow of sap is maintained, through the whole capillary network, until it is altogether exhausted of its nutritive matter. The source of the movement is thus entirely to be looked for in the changes, which take place in the act of growth; and the influence of heat, cold, and other agents, upon the movement, is exercised through their power of accelerating or retarding those changes.—The fluid which thus descends through the stem and roots, seems to be at last almost entirely exhausted; a portion of it appears to find its way into the ascending current, and to be mingled with the ascending current; but all the rest seems to have been entirely appropriated by the different tissues, through which it has circulated. Thus there is no need of any general receptacle, into which it may be collected, and from which it may take a fresh departure; such as is afforded by the heart of Animals. And as the purpose of this circulation is only to supply the nutritive materials, and not to convey oxygen,—this element being but little required in the vegetative processes, and being supplied by other means,—the same energy and rapidity are not required in it, as need to be provided for in the higher Animals.

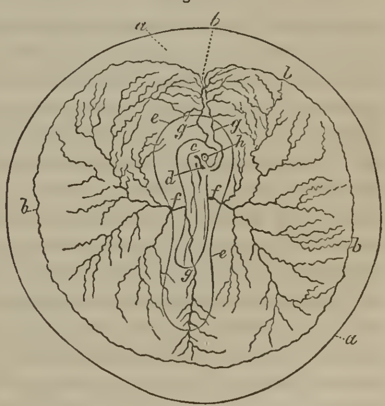
549. A condition of the Circulating system very similar to this, exists in several of the lower Animals, as well as in the embryo-state of the higher. In the very lowest, no blood-vessels are required, for the same reason that no sap-vessels exist in the lowest Plants;—namely, because every part absorbs and assimilates nutritious fluid for itself, so that it does not require a supply from vessels. As, in the Sea-Weeds, the whole substance is nourished by direct absorption from the fluid in contact with the *external* surface, every part of which seems endowed with the same absorbent power, so in the Polypes do we find, that the whole substance is nourished by direct absorption from the *internal* surface, which forms the lining of the digestive cavity. In the same manner, the Aëration of the animal fluids,—or the exposure of them to the air contained in water, by which they may part with carbonic acid and imbibe oxygen,—is provided for, not by any special respiratory organs, but by the contact of water with every part of the soft external and internal surfaces. Further, as the substance of their body is nearly of the same kind in every part, they do not require the continual interchange of the fluid distributed to its several portions. Thus no circulation is necessary, in these simple animals, either for the nutrition of their tissues, or for the aëration of the fluids. The same is the case with others of the lower tribes; as well as with the embryo of the higher Animals, at the earliest periods of their development. Thus the lower *Entozoa*, or parasitic worms, have a digestive cavity channeled out, as it were, in their soft gela-

tinous tissues; and from the walls of this, the nourishment is drawn by the several component parts of those tissues, without the mediation of vessels. And the embryo even of Man, in its early condition, consists of an aggregation of cells, each of which absorbs for itself from the nutritious fluid with which it is surrounded, and goes through all its functions independently of the rest.

550. Proceeding a little higher, we find the first appearance of proper vessels in the higher *Entozoa*, and in the *Acalephæ* or Jelly-fish. These vessels take up the nutritive fluid from the walls of the digestive cavity, on which they are spread out, just as the roots of Plants do from the soil. They then unite into trunks, by which the fluid is conveyed to the more distant parts of the structure, in the same manner as the ascending sap is conveyed to the leaves by the vessels of the stem and branches; and these trunks again subdivide, and form a network of capillary vessels, which are dispersed through the several parts of the fabric; some of them being very abundantly distributed upon a portion of the surface, which is particularly destined to perform the respiratory function. Through these capillary vessels, the fluid seems to move in very much the same manner, as through the system of anastomosing vessels in Plants;—that is, its motion is due, rather to forces which are developed during its circulation, than to any *vis a tergo* derived from the contractile power of a propelling organ. But there is this difference; that, after having traversed the minute vessels, and yielded up to the tissues a part of the solid matter which it contains, the fluid is collected again by other trunks, which convey it back to the point from which it started; there it is mingled with the fluid that has been newly absorbed, and with that which has undergone aëration; and it is then distributed, as before, through the general capillary network of the body.

551. Now this is very much the condition of the human embryo, at the time when vessels are first developed in its substance. These vessels are formed by the coalescence of cells; and from the contents of these cells, which have been imbibed from the yelk, the first blood seems to be derived. The first formation of blood-vessels takes place, not in that part of the embryonic structure which is to be developed into the perfect animal, but in a membranous expansion from it, which surrounds the yelk, and which answers the purpose of

Fig. 83.



Vascular Area of Fowl's egg, at the beginning of the third day of incubation;—*a*, *a*, yelk; *b*, *b*, *b*, *b*, venous sinus bounding the area: *c*, aorta; *d*, punctum saliens, or incipient heart; *e*, *e*, area pellucida; *f*, *f*, arteries of the vascular area; *g*, *g*, veins; *h*, eye.

a temporary stomach. A capillary network is formed in a limited portion of this membrane, termed the *vascular area* (Fig. 83); and this not by the branching of larger trunks, these trunks being subsequently formed by the reunion of the capillaries. The first movement of the blood is *towards* the central spot, in which the organs of the permanent structure are being evolved; and it takes place before the incipient heart has acquired any muscularity, so that it must be quite independent of any contractile force exerted by that organ. Here too, then, we perceive that the circulation is essentially *capillary;* and that it is sustained by forces very different from those, of which the action is most evident to us in the higher animals.

552. As we ascend the animal scale, however, we find that provision is made for a more regular and vigorous Circulation of the Blood, than that which exists in the lowest classes. Thus in the class of Echinodermata (including the Star-fish and Sea-Urchin), a portion of the principal vessel is peculiarly endowed with contractile power; and this may be seen in constant pulsation, like the heart of the higher animals,—alternately contracting, to propel the fluid it contains, through the vessels that issue from it,—and then dilating, to receive a fresh supply from the vessels that pour their contents into it. A similar provision is observable in the lower tribes of Worms, in which this contractile vessel lies along the back; propelling the blood forwards, by a sort of peristaltic movement, through trunks which pass out at its anterior termination; and receiving it again, after it has circulated through the system, by vessels which enter at its posterior extremity. In the higher orders of Worms, in the Myriapoda or Centipede tribe, and in Insects, we find this dorsal vessel divided by transverse partitions containing valves, into separate cavities which answer to the different segments of the body. Each of these is, to a certain extent, the heart of its own segment, receiving and propelling blood by trunks which open into it; but they all participate in the more general circulation just described, a large portion of the blood being poured into the hindermost segment, transmitted forwards from cavity to cavity through the valves which separate them, and at last propelled through trunks that issue from the most anterior segment. In some instances we find that two or three of these trunks, on either side, pass round the œsophagus, and reunite below it, so as to enclose it in a sort of collar; and they form a main trunk by this union, which runs backwards along the under surface of the body, and which distributes the blood to its different organs by lateral branches. These subdivide into a capillary network; and the returning vessels, which originate in this network, pour the blood which has circulated through it into the posterior cavity of the dorsal vessel.—Still it is very evident, from the observation of the circulation in those transparent species, in which the whole process can be distinctly watched under the Microscope, that the contractile power of the dorsal vessel is far from sufficient of itself to sustain the Circulation; and that the movement of the blood through the capillary net-

work is in part due to forces developed during its progress,—being often retarded or accelerated in particular spots, without any visible change in the propelling force of the central organ.

553. In most of these animals, there are distinct organs of Respiration, confined to some one part of the body; and we often find that the vessels which convey blood to them, are furnished with distinct contractile portions, like so many supplementary hearts, for the purpose of propelling the blood through them more energetically. In proportion as we ascend the series of Articulated animals, do we find, for the most part, a more vigorous and regular circulation, both for the nutrition of the system, and for the transmission of the blood through the respiratory organs; but there is an exception in the case of Insects, which deserves special notice. In this class, the circulation is much less vigorous than it is in other Articulated animals of similar complexity of structure; though it might have been anticipated, that the extraordinary activity of their movements would necessitate a corresponding rapidity in the circulating current, especially for the purpose of conveying an extraordinary supply of oxygen to the nervous and muscular systems. But this is provided for in another way; the air being conveyed to these tissues, not through the blood, but by direct transmission through the minute ramifications of the air-tubes or tracheæ, which penetrate the very smallest organs of the body.

554. The condition of the Circulating apparatus in the Embryo of higher animals, at a period a little advanced beyond that just alluded to, presents a striking analogy with that last described; for the heart, at the time of its first formation, seems like a mere dilatation of the principal vascular trunk, having thickened walls, in which, after a time, muscular fibre begins to be developed, and the contractile power manifests itself. The pulsation of this heart, however, does not seem to extend its influence immediately through the vascular area; the capillary circulation in which, remains for some time in great degree independent of it. There is no resemblance in *form*, however, between the dorsal vessel of Insects, and the incipient heart of the higher animals; since the latter is never much prolonged, and speedily becomes doubled (as it were) upon itself; and its first division into distinct cavities is merely for the purpose of separating its *receiving* portion, or *auricle*, from its *propelling* portion, or *ventricle*. But the general *condition* of the Circulating system is much the same in the two cases; and it is further alike in this,—that it is not always easy to show that the vessels have distinct walls, as they frequently seem like mere channels excavated in the tissues.

555. We may next turn our attention briefly to the condition of the Circulating apparatus in the *Molluscous* classes, which has lately been found to present some very peculiar characters. In these it would seem as if the moving power were more concentrated in the heart, than in the preceding; for this organ seems no longer like a mere dilatation of the vascular trunk, but is a distinct sac with mus-

cular walls, usually having at least two cavities, an auricle and a ventricle. The usual course of the circulation is the following. The blood, expelled from the ventricle of the heart, passes along the main systemic artery, or aorta; which distributes it to the body at large. It is then collected again, and transmitted to the respiratory organs; in which it is exposed, either to the air contained in the surrounding water, or (in the terrestrial Mollusks) more directly to the atmosphere; and from these it is returned to the heart, to be again transmitted to the system. Thus we see that the heart of these animals receives and impels *aërated* blood; and that its office is to send that blood to the capillaries of the general system. Hence it may be called a *systemic* heart.

556. The blood, in the first part of its course, passes through distinct vessels: it has been lately shown, however, that in the Mollusks in general, the blood which has passed through the systemic capillaries, and is on its way to the respiratory organs, is no longer thus confined, but that it meanders through passages or sinuses, which are channeled out in the tissues, and which even communicate freely with the abdominal cavity in which the viscera lie; so that their whole exterior is bathed by the circulating fluid. It is perhaps in this part of its course, that it most readily takes up the fresh nutrient materials, which have been prepared by the digestive process, and which would, under such circumstances, find their way with comparative facility from the inner surface of their walls to the outer.—After being thus diffused, in its venous or carbonized state, through the substance of the tissues and through the visceral cavity, it is again collected into distinct trunks; and these convey it to the respiratory organs.—Now although it cannot be doubted, that the impelling power of the heart is the chief cause of the movement of the blood through the systemic vessels, yet it would seem impossible to suppose, that this power can be exerted over the unrestrained currents, in which it is diffused through the body, after passing through the systemic capillaries; and it can scarcely be doubted, that its passage through the capillaries of the respiratory organs is due to the power which is developed in themselves, under the conditions already alluded to.

557. There is a very curious phenomenon to be observed in the circulation of some of the lowest Mollusks; namely, the continual *reversal* of the course of the current. The heart, in these animals, is much less perfectly formed, than in the higher tribes; and seems more like the mere contractile dilatation of the principal trunk, which is the sole representative of that organ in the Echinodermata. The circulating fluid is sometimes transmitted first to the system; and, after being distributed to its different parts by the ramifications of the main artery, it meanders through the channels excavated in its tissues; and then flows towards the respiratory surface, after passing over which, it returns to the heart. But after a certain duration of its flow in this direction, the current stops, and then recommences in the contrary direction,—proceeding first to the respiratory organs, and

then to the system in general. It would seem as if in this, one of the lowest forms of animals possessing a distinct Circulation, the central power were not yet sufficiently strong, to determine the course which the fluid is to take ; so that it undergoes continual vacillations. In a group of Compound Polypes, to which this class of Mollusks has many points of affinity, there is a movement of fluid through the stem and branches, which in like manner continually changes its direction. This movement, however, can scarcely be regarded in the light of a proper Circulation ; since the tubes in which it occurs are in direct communication with the digestive cavities of the Polypes. But the flow seems altogether independent of any mechanical propulsion ; and takes place most energetically and regularly towards parts in which new growth is going on.

558. We have now to consider the chief forms in which the Circulating apparatus presents itself in the Vertebrated classes ; and first in that of *Fishes*. We have here, as in Mollusks, a heart with two cavities, an auricle and a ventricle ; this heart, however, is not placed at the commencement of the systemic circulation, but at the origin of the respiratory vessels. The blood which it receives and propels, is venous or carbonized ; this is transmitted along a main trunk, which speedily subdivides into lateral branches or arches ; and these distribute it to the fringes of gills, that hang on the sides of the neck. By the action of the water on the gills, the blood is aërated in its passage through them ; and it is then collected by a series of converging vessels, which reunite to form the great systemic artery, or aorta. By the ramifications of this artery, the blood, now aërated, is distributed through the system, and affords the requisite nourishment and stimulation to its tissues. Returning from the systemic capillaries in a venous state, the blood of the head and anterior portion of the body finds its way at once into the great systemic vein, or vena cava, by which it is conveyed back to the auricle of the heart ; but that which has traversed the capillaries of the posterior part of the body, and of the abdominal viscera, is conveyed by a distinct system of veins to the liver and the kidneys. In these organs, the veins again subdivide into a network of capillaries, which is distributed through the secreting structure, and which serves to afford to the secreting cells the materials of their development. This is termed the *portal* system of vessels. From the capillaries of the liver and kidneys, the blood is finally collected by the hepatic and renal veins, which convey it into the vena cava;

Fig. 84.

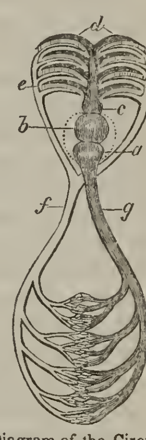


Diagram of the Circulating Apparatus of Fishes;—*a*, the auricle ; *b*, the ventricle ; *c*, the trunk supplying the branchial arteries, *d*, the aërated blood returning from the gills is conveyed by *e*, *e*, the branchial veins, to *f*, the aorta, which distributes it to the system ; thence it is collected, and returned to the auricle, by the veins which unite in the vena cava, *g*.

where it is mingled with the blood that has not passed through those organs, and is thus conveyed to the heart.

559. The heart of Fishes, then, belongs to the *respiratory* circulation. It propels venous blood to the capillaries of the gills, in which it is aërated; returning from these, the aërated blood is transmitted through a second set of capillaries, those of the system, in which it again becomes venous; whilst a portion of this blood is made to traverse a third set of capillaries, those of the liver and kidneys, before it is again subjected to the propelling power of the heart. Now as the heart, instead of being stronger than it is in animals with the complete double circulation presently to be described,—in which the greater part of the blood propelled by it only traverses one set of capillaries, and never more than two,—is much weaker in proportion, it is evident that here, too, a supplementary power must exist, by which the flow of blood through the capillaries is aided, and on which, indeed, the portal circulation must greatly depend.

560. It is requisite that, in the class of Fishes, the *whole* of the venous blood returned from the system should pass through the respiratory organs before being again transmitted to the body; since the aërating action of the small quantity of air diffused through the water, would otherwise be insufficient for its renovation. But in Reptiles, all of which breathe air during their adult condition, the case is very different; for if the whole current of their blood were exposed to the atmosphere, before being again sent to the body, the quantity of oxygen conveyed into the tissues would be too great, and would have an over-stimulating effect. The plan of the Circulation is, therefore, differently arranged in Reptiles. We find the heart to consist of three cavities; two auricles and one ventricle. From the ventricle issues a single trunk, which speedily subdivides; some of its branches proceeding to the lungs, and others to the body. The blood which is transmitted through this trunk, is of a mixed character, as we shall presently see; being neither fully aërated, nor yet highly carbonized. It contains sufficient oxygen, to stimulate the nervous and muscular systems of these comparatively inert animals; whilst it also contains enough of carbonic acid, to require being exposed to the atmosphere through the medium of the lungs. The blood which has passed through the systemic capillaries, and which has been thereby rendered completely venous, is returned to one of the auricles—the systemic—by the vena cava. On the other hand, the blood which has passed through the capillaries of the lungs, and which has been thereby rendered completely arterial, is returned through the pulmonary vein to the other auricle,—the pulmonary. Thus one of the auricles exclusively receives aërated, and the other carbonated blood; and as both pour their contents into the common ventricle, the blood which that cavity contains and propels is of a mixed character.

561. An extremely interesting aspect of the circulating apparatus is presented by the *Amphioxus* or Lancelot; an animal which presents

the general form of a Fish, and which can scarcely be referred to any other group ; but in which the characters of the Vertebrated series are degraded (as it were) to the level of the lowest Molluscous and Vermiform classes. The blood, which is white, moves through distinct vessels, but there is no proper heart ; and the vascular trunks present several dilatations, in different parts, which have muscular walls, and show contractile power. Thus the circulation is carried on, not through the agency of a central impelling organ, as in Fishes ; but by power which is scattered or diffused through various parts of the system of blood-vessels, as in the lower Invertebrata.—The respiratory apparatus, also, is formed upon a type much lower than that of Fishes ; for it consists simply of a dilatation of the first part of the alimentary canal, or pharynx, upon the walls of which the blood is distributed in divided streams, its cavity being filled with water, which serves to aërate the blood. This is precisely the type, on which the respiration is effected, in those lowest Mollusks, of which mention has just been made, as exhibiting alternations in the direction of the circulating current (§ 557). In other respects, however, the arrangement of the vascular system in this extraordinary animal, corresponds with that which obtains in Fishes.

562. Various modifications of this form of Circulating apparatus exist in the different groups of *Réptiles*. In the lowest among them, which breathe permanently by gills like Fishes, besides possessing imperfectly developed lungs, the apparatus exhibits a blending of both plans ; for a small portion of the blood, which is propelled by each contraction of the ventricle, passes directly to the lungs ; the principal part of it being at once distributed to the gills as in Fishes. After passing through these, it is transmitted to the general system ; and on returning thence, in a completely venous state, it is mingled with the blood which has been arterialized in the lungs. This latter, however, bears so small a proportion to the rest, that, if the aëration were not partly effected by the gills, it would be insufficient for the wants of the animal.—The tadpoles of the common Frog and Water Newt, as well as of other species which, like them, begin life in the general condition of Fish, present a similar condition at one period of their change. At first, the whole aëration is effected by means of gills, the lungs being in a rudimentary or undeveloped state ; and the entire circulation is carried on as in Fishes, the pulmonary vessels being scarcely traceable. As the lungs begin to be developed, however, a portion of the blood is sent to them ; and at the same time, communicating passages which previously existed, between the vessels that convey blood to the gills, and those that return it from them, are increased in size ; so that a certain proportion of the blood is transmitted to the system, without having passed through the gills at all. By a further increase in the diameter of these, the whole current of blood takes this direction, the gills being no longer serviceable ; and as, at the same time, the lungs are attaining their full development, the aëration which they effect in the blood transmitted to them be-

comes sufficient, and the whole circulation is thus permanently established on the Reptile type.

Fig. 85.

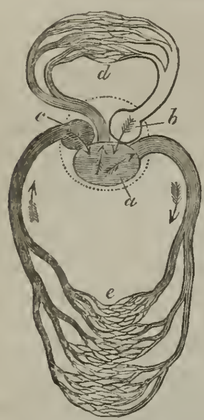


Diagram of the Circulation in Reptiles:—*a*, single ventricle, receiving the aërated blood from *b*, the pulmonary auricle, and venous blood from *c*, the systemic auricle; and propelling part of this mixed fluid to the pulmonary capillaries *d*, and part to the systemic capillaries, *e*.

563. On the other hand, among the higher Reptiles, we find the circulating apparatus presenting approaches to the form it possesses in Birds and Mammals. For the ventricle is divided, more or less completely, into two cavities, one of which propels aërated blood to the system, whilst the other transmits venous blood to the lungs. A certain amount of mixture of arterial and venous blood always takes place, however, either in the heart itself, or in the vessels; so that the blood which the body receives is never purely arterial. But this mixture is sometimes effected in such a manner, that pure arterial blood is sent to the head and anterior extremities; though the remainder of the body receives a half-aërated fluid. This is accomplished in the Crocodile, by a provision very similar to that which exists in the fœtus of warm-blooded animals (Chap. XI). The *portal* circulation in Reptiles is carried on nearly upon the same plan as in Fishes. It receives the blood from the posterior extremities and from the tail, as well as from the abdominal viscera; and this blood is distributed by the portal capillaries, not only through the liver, but also through the kidneys, although the latter also receive arterial branches from the aorta. The fact that the kidneys are supplied from the general portal circulation, in Fishes and Reptiles, has an important bearing on the difference in the arrangement of their own vessels, which will be hereafter shown to exist, between the kidneys of these animals, and those of Birds and Mammals (§ 727).

564. In the warm-blooded division of the Vertebrated series, which includes the classes of Birds and Mammals, we find the whole circulation possessed of a greatly increased energy; but the distinguishing peculiarity of the apparatus in these animals, is that conformation of the heart and vessels, which secures a *complete double circulation* of the blood;—that is, which provides for the aëration of every particle of the venous blood which has returned from the system, before it is again sent into the tissues. The heart may be regarded as consisting of two distinct parts,—a *systemic* heart, like that of the Mollusks, forming its left side,—and a *respiratory* heart, like that of Fishes, constituting its right. Each of these parts has a receiving cavity or auricle, and an impelling cavity or ventricle. The cavities of the two sides are completely separated from one another, in the adult state at least; though their walls are united, for economy of material.

It is obvious that much is saved in this manner; since, as the contractions of the auricles and of the ventricles on the two sides occur simultaneously, the pressure of blood in the one is partly antagonized by that on the other, wherever it acts on the wall that is common to both. This antagonism is not complete, however; since the systemic ventricle contracts with far greater force than the pulmonary; and the wall between them must be capable of resisting the difference of pressure on its two sides thus occasioned.—The blood which is returned from the system, in a venous state, through the vena cava to the right auricle, and which is poured by it into the right ventricle, is impelled by the latter through the capillaries of the lungs, where it undergoes aëration. Returning thence, in an arterialized state, it is conveyed into the left auricle, and thence flows into the left ventricle; by which it is propelled through the great systemic artery or aorta, and through its ramifications to the general system.

Fig. 86.

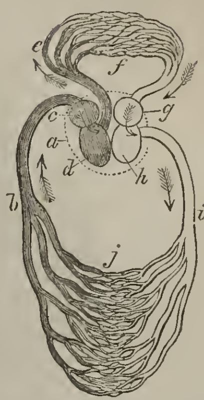
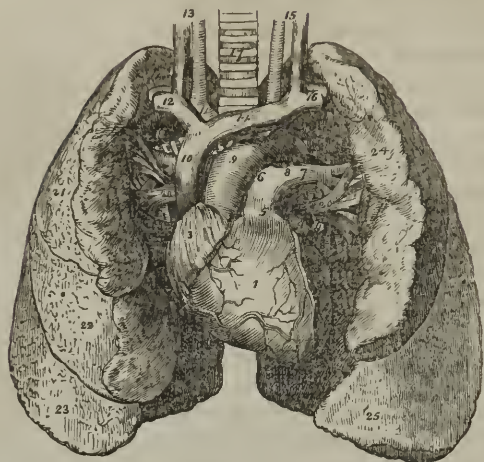


Diagram of the Circulating Apparatus in Mammals and Birds:—*a*, the heart containing four cavities; *b*, vena cava, delivering venous blood into *c*, the right auricle; *d*, the right ventricle, propelling venous blood through *e*, the pulmonary artery, to *f*, the capillaries of the lungs; *g*, the left auricle, receiving the aërated blood from the pulmonary vein, and delivering it to the left ventricle, *h*, which propels it through the aorta *i*, to the systemic capillaries, *j*, whence it is collected by the veins, and carried back to the heart through the vena cava, *b*.

565. The greater part of the blood, which has been rendered venous by passing through the systemic capillaries, is collected by the systemic veins, and is returned directly to the heart through the vena cava. But a portion is still employed for the distinct circulation, which is destined to supply the materials for the secreting action of the liver. The blood that has traversed the capillaries of the walls of the alimentary canal, and of the other viscera concerned in digestion, is collected again by the converging veins into a large venous trunk, the *vena portæ*, by which it is distributed through the liver. This vessel, although formed by the convergence of veins, and conveying venous blood, has really the character of an artery in an equal degree; for it subdivides and ramifies after its entrance into the liver, so as to form a network of capillaries, from which the blood is again collected, and thence transmitted by the hepatic vein to the vena cava.—Thus that portion of blood, which supplies the liver with the materials of its secreting action, passes through two sets of capillaries, between the time of its leaving the heart and its return to it. The portal circulation in Birds, as in Reptiles and Fishes, receives the blood from the posterior part of the body, and from the extremities; but the portal blood is only conveyed to the liver; the kidneys being supplied by the renal artery.

Fig. 87.



Anatomy of the human heart and lungs. 1. The right ventricle; the vessels to the right of the figure are the middle coronary artery and veins; and those to its left, the anterior coronary artery and veins. 2. The left ventricle. 3. The right auricle. 4. The left auricle. 5 The pulmonary artery. 6. The right pulmonary artery. 7. The left pulmonary artery. 8. The remains of the ductus arteriosus 9. The arch of the aorta. 10. The superior vena cava. 11. The right arteria innominata, and in front of it the vena innominata. 12. The right subclavian vein, and behind it its corresponding artery. 13. The right common carotid artery and vein. 14 The left vena innominata. 15. The left carotid artery and vein. 16. The left subclavian vein and artery. 17. The trachea. 18. The right bronchus. 19. The left bronchus. 20, 20. The pulmonary veins; 18, 20, form the root of the right lung; and, 7, 19, 20, the root of the left. 21. The superior lobe of the right lung. 22. Its middle lobe. 23. Its inferior lobe. 24. The superior lobe of the left lung. 25. Its inferior lobe.

566. This perfect form of the Circulating apparatus is only attained, in the warm-blood animal, after a series of transformations, which strongly remind us of the permanent forms presented by the vascular system in Fishes and Reptiles. Thus in the embryo of the Chick at about the 60th hour, and in that of the Dog at about the 21st day, the curved and dilated tube, of which the heart previously consisted, (§ 554,) is found to be distinctly divided into an auricle and a ventricle. From the latter originates the main arterial trunk, which divides into four pairs of lateral branches; and these pass round the pharynx precisely in the position and direction of the arteries of the gills of Fishes. They do not, however, distribute the blood to gill-tufts; for none such are developed in the embryo of the warm-blooded animal: but they meet again below the pharynx, to form a trunk, which supplies the general circulation.—Within a short period, however, the whole plan of the circulation undergoes a change. The auricle and the ventricle are each divided by a partition, that is developed in the middle of the heart; and thus the two auricles and the two ventricles are formed. Whilst this is going on, a change takes place also in the vessels that arise from the heart; for the arterial trunk, that was previously single, undergoes a division into two distinct tubes; one of which is connected with the left ventricle, and

becomes the aorta, whilst the other originates in the right ventricle, and becomes the pulmonary artery. Of the four pairs of branchial arches, some are subsequently obliterated; whilst others undergo changes that end in their becoming the arch of the aorta, the right and left pulmonary arteries, and the right and left subclavians.

567. The muscular power of the heart is much greater in the warm-blooded than in the cold-blooded Vertebrata, in proportion to the extent of the circulation which it is concerned in maintaining; and it is evidently destined to take a much larger share in the propulsion of the fluid, than it is in the lower tribes. Many Physiologists, indeed, are of opinion that the movement of the blood is *entirely* due to the action of the heart; and this view appears to be supported by the results of numerous experiments upon the circulation. But it is very difficult, if not impossible, to make experiments that shall be really satisfactory upon this point; and it appears safer to trust to the "experiments ready prepared for us by Nature," as Cuvier termed them,—namely, those lower forms of animated being, in which various diversities of structure present themselves, and in which we can study the regular and undisturbed effects of these.—Thus we have seen that, in Plants and the lowest Animals, which have no central impelling cavity, the movement of the nutritive fluid is entirely dependent upon the power that is diffused through the network of vessels in which it circulates. As we ascend the series, we find an organ of impulsion developed upon a certain part of the vascular system, whose object it is to give increased energy and regularity to the movement. And ascending still higher, we find the moving power gradually concentrated, as it were, in this organ; yet it is not altogether withdrawn from the capillary network, as we shall see from several facts to be presently adduced. The particular actions of the Heart, the Arteries, the Capillaries, and the Veins, will now be considered in more detail.

3. *Action of the Heart.*

568. The Heart is a hollow muscle, endowed in an eminent degree with the property of *irritability;* by which is meant, the capability of being easily excited to movements of contraction alternating with relaxation (§ 347). At first sight, its actions seem different from that of the muscles, which are called into action by the impulse of the will; for in these there is apparently no such alternation, the state of contraction being kept up as long as the will operates. But it has been already explained that, even in these, the individual fibres are probably in a state of continual alternation of contraction and relaxation, during their active condition,—one set taking up the action, whilst another is returning to the state of relaxation. Hence the chief peculiarity in the Heart's action consists in this,—that the whole mass of fibres of each division of the organ contract and relax *together.* The contraction of the two ventricles is perfectly synchronous, as is that of

the two auricles; but the contraction of the auricles is synchronous with the dilatation of the ventricles, and vice versâ. The regularity of this alternation, however, is somewhat disturbed, when the irritability of the heart is becoming exhausted; and both sets of movements will continue, when the auricle and ventricle have been separated from one another. Their regular succession, in the natural state, is doubtless in part due to the fact, that the transmission of blood from the auricle into the ventricle, by the contraction of the former, is the stimulus which most effectually excites the latter to contraction; whilst the ventricle is contracting, the auricle, now free to dilate, is distended by the flow of blood from the veins that open into it; and this flow stimulates it to renewed contraction, just at the time when the contraction of the ventricle has been completed, and *its* state of relaxation enables it to receive the blood poured in through the orifice leading from the auricles.

569. In the living animal, the auricular and ventricular movements succeed one another with great regularity; and when the circulation is proceeding with vigour, scarcely any appreciable pause can be discovered between the different acts. The contraction or *systole* of the Auricle takes place precisely at the same moment with the dilatation or *diastole* of the Ventricles; and, as soon as the latter are full, and the former are empty, the diastole of the Auricles, and the systole of the Ventricles, immediately succeed. The systole of the Ventricles occasions the propulsion of blood into the arterial system; and this action produces the *pulse*, as will be explained hereafter. And it also corresponds with the *impulse* or stroke of the heart against the parietes of the chest. This impulse is not produced, as some have supposed, by the swinging of the entire heart forwards; but by the peculiar mode in which the Ventricular systole takes place. In the contraction of its walls, every dimension is lessened; but *shortening* is the most perceptible change, the vertical diameter of the Ventricle being the greatest. Owing to the peculiar spiral disposition of the fibres of the heart, its apex is not simply drawn upwards by their contraction, but it is made to describe a spiral movement, from right to left, and from behind forwards; and it is in this manner, that it is caused to strike against the side of the chest.

570. The systole of the Ventricles is immediately followed by their diastole; but the commencement of this has been observed to occur at a small interval previous to the contraction of the Auricles; and sometimes a brief interval of repose may be noticed, separating the *first* stage of the Ventricular diastole, which may be partily due to the simple elasticity of the walls of the Ventricles, from the *second*, which is accompanied by the systole of the Auricles, and in which the blood of the latter is forcibly propelled into them. When the circulation is being carried on regularly, the blood is propelled into the Ventricles with sufficient force to dilate them strongly; so that the hand closed upon the heart is opened with violence. Even the auricles dilate with more force than it seems easy to account for by the *vis a tergo*

of the blood in the venous system; which is small compared with that which the fluid possesses in the arteries.

571. The natural movements of the Heart are accompanied by certain sounds, which are heard when the ear is applied over the cardiac region; and an acquaintance with these sounds and with their causes is of much importance, since the alterations which they undergo in disease, afford us some of our most accurate information in regard to the nature of the morbid affection. Concurrently with the *impulse* of the heart against the chest, a dull and prolonged sound is heard; this, which is termed the *first* sound, marks the ventricular systole, and is synchronous with the pulsation in the arteries. The second sound, which is short and sharp, follows *immediately* upon the conclusion of the first; and it must therefore be produced during the first stage of the Ventricular diastole, before the systole of the Auricles has commenced. It is followed by a brief interval of repose, which occurs during the remainder of the Ventricular diastole and the Auricular systole; and this is succeeded by a recurrence of the first sound. If the whole period between two successive pulsations be divided into four parts, it is estimated that the first sound usually occupies two of these; and the second sound, and the interval, one part each.

572. Now in order to understand the causes of these sounds, it is necessary to study the course of the blood through the heart a little more in detail. When the Ventricles, distended with blood, are contracting upon their contents, they eject them forcibly through the narrow orifices of the aorta and pulmonary artery; and the semilunar valves, which guard these orifices, are thrown back against the walls of the arteries. The regurgitation of the blood into the auricles is prevented by the action of the mitral and tricuspid valves; but the flaps of these do not suddenly fall against each other, when the blood first begins to press them together; being restrained by the *chordæ tendineæ*. The connection of these with the *carneæ columnæ*, which form part of the ventricular walls, and contract simultaneously with them, appears to have this use:—that the flaps of the valves, which are completely thrown back during the preceding rush of blood from the auricles to the ventricles, may be drawn into a favourable position, for the blood to get behind them and bring them together, so as completely to close the orifice. As soon as the ventricular diastole begins to take place (even before the contraction of the auricles has commenced) there will be a tendency of the blood, that has just been propelled into the aorta and pulmonary artery, to flow back to the heart; but this regurgitation is completely prevented by the semilunar valves of these orifices, which are immediately filled out by this backward tendency of the blood, and which meet in such a manner as completely to close the orifices. This closure is much more sudden than that of the mitral and tricuspid valves, being altogether unrestrained.

573. The *first* sound is certainly *in part* due to the impulse of the heart against the thoracic parietes; as is proved by the fact, that when

the impulse is prevented, the sound is much diminished in intensity; and also by the circumstance, that, when the ventricles contract with vigour, the greatest intensity of the sound is over the point of percussion. But that it is *not entirely* due to this cause, is also sufficiently evident from two circumstances;—its prolonged character, which could scarcely be given by a momentary impulse;—and its continuance, though with diminished intensity, when the parietes of the chest are wanting, and even after the complete removal of the heart from the body. Moreover, the duration of the first sound is much increased by any morbid state of the orifices of the ventricles, which obstructs the exit of the blood. Much discussion has taken place as to the cause of that part of it, which is not due to the impulse; some having attributed it to the muscular contraction of the walls of the ventricles, others to the flow of blood over the irregular surfaces of their interior, and others to the rush of the fluid through the narrow orifices leading to the aorta and pulmonary artery. There can be little doubt, that the first and last of these causes are both concerned in producing the sound. For as a sound may be distinctly heard by means of the stethoscope, when the heart is contracting vigorously out of the body, and when no blood is propelled by it, nothing else than muscular contraction can be then regarded as its source; and there is other evidence that sound may be produced by this cause, since the vigorous contraction of any other large muscle gives rise to a continued tingling, which may be heard through the stethoscope. But when the heart is contracting in its natural position, and is propelling the blood with its ordinary vigour, the sound is heard in its greatest intensity at the *base* of the heart, *i. e.*, at the origin of the great arteries; and since any obstruction to the exit of the blood through them increases the intensity, as well as the length of the sound, it can scarcely be doubted that it is partly due to the rush of the blood through the contracted entrances of these vessels. A very similar sound, known as the "bruit de soufflet," or bellows-sound, may be heard through the stethoscope, over any large artery, when it is compressed, so as to permit the passage of blood less readily than usual. Thus the ordinary first sound may be regarded as composite in its nature; being made up of the sound produced by the impulse of the heart against the parietes of the chest, of the muscular sound occasioned by the forcible contraction of the thick walls of the ventricles, and of the sound generated by the friction of the particles of blood against each other, and against the boundaries of the narrowing orifices which lead into the vessels.

574. The cause of the *second* sound is simpler, and more easily understood. It is due to the sudden filling-out of the semilunar valves with blood, at the moment when the ventricular systole has ceased, and when the commencing diastole produces a tendency to the regurgitation of blood from the aorta and pulmonary artery. The sudden passage of the valves, from a state of complete relaxation to one of complete tension, occasions a sort of *click;* which is the second sound

of the heart. That this is the real cause, has now been fully demonstrated. If one of the valves be hooked back against the side of the artery, by the introduction of a curved needle, so that a reflux of blood is permitted, the sound is entirely suppressed. And if the complete closure of the valves be prevented by disease, so that their tension is diminished, and a certain amount of regurgitation takes place, the second sound is no longer heard in its proper intensity; whilst, on the other hand, a sound analogous to the first, and sometimes prolonged over the whole interval of repose, indicates the reflux of the blood into the ventricles. When the semilunar valves are thickened by morbid deposit, their surface roughened, and their opening narrowed, the *first* sound becomes harsher and sharper; and the *second* sound acquires the same character,—the backward as well as the forward flow of the blood being affected by this cause.

575. The natural movements of the mitral and tricuspid valves appear to be accomplished with perfect freedom from sound; for the size of the orifices which they guard prevents any considerable friction of the blood, in its flow from one cavity to the other; and their closure, when the ventricular systole begins, does not take place with the rapidity and suddenness of that of the semilunar valves. But when their structure is changed by disease, their action is not so noiseless; and they give rise to various morbid sounds, which are heard in addition to the ordinary sounds, and which may even obscure them altogether.—In the same manner the ordinary movements of the heart do not produce any audible friction sound, between the two surfaces of the pericardium, that which covers the heart and that which lines the pericardial sac. These surfaces are kept moist, in health, by the serous fluid constantly exhaling from them; and they are extremely smooth; so that they glide over one another noiselessly. But if they become dry, as in the first stage of inflammation, a slight creaking is heard, accompanying *both* the ordinary sounds of the heart, and somewhat resembling the rustling of paper. And if they are roughened by the deposit of inflammatory exudations, this " to and fro" sound becomes of a harsher character.

576. The walls of the left Ventricle are considerably thicker than those of the right; and the contractile power is greater. This difference is obviously required, by the difference in length between the systemic and the pulmonary vessels; the amount of force necessary to drive the blood through the latter being far inferior to that which is requisite to propel it through the former. The average thickness of the walls of the *left* Ventricle is about $4\frac{1}{2}$ lines; being somewhat greater than this at the middle of the heart, and less at its apex. The average thickness of the walls of the *right* ventricle is not more than $1\frac{1}{2}$ line; being a little greater than this at the base, and less at the apex of the heart. The left auricle is somewhat thicker than the right.—The capacities of all the four cavities are nearly equal; each of them, in the full-sized heart, holding about two ounces of fluid. The Ventricles are, perhaps, a little larger than their respective Auricles; but there

is no very positive difference in capacity, between the Ventricles and Auricles of the two sides.

577. The quantity of blood which is propelled at each Ventricular systole, cannot, therefore, exceed two ounces; and it is probably somewhat less, as the ventricles do not seem to empty themselves completely at each contraction. Now the whole quantity of the blood seems to be about one-fifth of the entire weight of the body; so that it will amount to about 28 lbs. in an individual of 140 lbs. weight. Allowing 75 pulsations to a minute, 150 ozs. (or 9lbs. 6 ozs.) of blood would pass through each ventricle of the heart in that time; consequently nearly three minutes would be required for the passage of the entire mass of the blood through the whole circle of its movement, if its rate be entirely determined by the impulses it receives from this central organ.—But it appears, from various experiments, that the rate of circulation is much more rapid than this. For if a solution of any salt easily detectible in the blood, be injected into one of the large veins near the heart, it may be traced in the arterial circulation in from 15 to 20 seconds afterwards; during which interval it must have traversed the whole pulmonary system of vessels and passed through both sides of the heart. And if the salt be one which acts powerfully on the heart itself,—as is the case with Nitrate of Baryta or Nitrate of Potass,—this action is manifested almost at the same moment with the appearance of the salt in the arteries of other parts; thus showing that it has been conveyed by the coronary arteries into the capillaries of the heart itself. The period required for the transmission of a saline substance from the veins of the upper part of the body to those of the lower,—which can scarcely be accomplished through any more direct channel than the current that returns to the heart, then passes through the lungs back to the heart again, and then flows through the systemic arteries and capillaries to the veins,—is accomplished in little more than 20 seconds, even in an animal so large as a Horse. It appears, then, that even the vigorous and constant action of the Heart is not alone sufficient to maintain the circulation at its ordinary rate; and we are not justified, therefore, in excluding those sources of movement in the higher animals, which evidently exert so important an influence in the lower.

578. The force with which the heart propels the blood is such, that if a vertical pipe be inserted into the Carotid artery of a horse, the blood will sometimes rise in it to a height of 10 feet. From comparative experiments upon other animals, it has been estimated that the vigorous action of the heart in Man would sustain a column of blood in his aorta about 7½ feet high; or, in other words, that the force with which the heart ordinarily propels the blood through the aorta, is equal to that which would be generated by the weight of a column of blood of the same size, and 7½ feet high; which weight would be about 4⅓ lbs. But the force which must be exerted by the heart to sustain such a column, may be shown, upon physical principles, to be as much greater than this as the area of a plane passing through

the base and apex of the left ventricle is greater than that of the transverse section of the aorta; and as the proportion of these areæ is about 3·1, the real force of the heart may be stated at about 13 lbs.

579. The number of contractions of the heart, in a given time, is liable to great variations within the limits of health, from several causes; the chief of which are diversities of Age and Sex, amount of Muscular exertion, the condition of the Mind, the state of the Digestive system, and the period of the Day.—The following are the points of greatest importance, in regard to the action of these several influences:

Age.—The pulse of the newly-born infant averages from 130 to 140 per minute; and this rate gradually diminishes, until, in adult age, the pulse averages from 70 to 80; and in the decline of life from 50 to 65.

Sex.—The pulse of the adult female exceeds that of the adult male in frequency, by about 10 or 12 beats in a minute; and it is also more liable to disturbance from other causes.

Muscular exertion.—The effect of this in accelerating the pulse is well known; but as the amount of change depends upon the degree of exertion, no general statement can be made on the subject. The continued influence of a moderate degree of muscular exertion, is shown by the effect of *posture* upon the pulse. Thus the pulse is on the average from 7 to 10 beats faster (per minute) in the standing than in the sitting posture; and 4 or 5 beats faster in the sitting than in the recumbent posture. This amount of variation is temporarily increased by the muscular effort required for the *change* of posture; but this soon subsides into the continued rate, which the permanent maintenance of the new posture involves. There are certain states of the system, in which the heart's action is increased to a most violent degree, by a simple change of posture; and in which, therefore, it is necessary that even this slight movement should be made with gentleness and caution.

Mental Condition. The action of the heart is peculiarly influenced, as every one is aware, by the excitement of the *emotions*. This is a fact to which, however familiar, the medical practitioner should constantly direct his attention. The trifling agitation occasioned by the entrance of the medical man will produce, in many patients, such an acceleration of the pulse, as would be very alarming, if its true cause were not known. And the real rate of the pulse cannot be ascertained, until time has been permitted for the agitation to subside; which is favoured, also, by the influence of a gentle manner and tranquilizing conversation. The operation of the *intellectual* powers does not seem to affect the rate of the heart's movement in any other way, than by inducing a general state of feverishness, if it be too long or too energetically kept up.

State of the Digestive System.—The pulse is quickened during the digestion of a meal; but no exact numerical statement can be made on this subject.

Period of the Day.—The frequency of the pulse appears to be some-

what greater in the morning than it is in the evening; and the temporary action of any of the preceding causes more quickly subsides in the evening than in the morning.

580. The movements of the heart have been supposed to depend upon a constant supply of nervous influence, generated by the cerebro-spinal system, and transmitted through the sympathetic nerve, the branches of which are copiously distributed to it. And this idea seemed to derive support from the fact, that, when the brain and spinal cord are removed, or when large portions of them are suddenly destroyed, by crushing or by the breaking up of their substance in any other mode, the movements of the heart are arrested. But it has been shown that the brain and spinal cord may be *gradually* removed, without any such consequence; and the occasional production of fœtuses destitute of those centres, but possessing a regularly-pulsating heart, is another proof that the movements of this organ do not *depend* upon a supply of nervous influence derived from them. Still they are capable of being influenced by impressions transmitted through the nerves. It has been ascertained by Valentin, that, after the heart has ceased to beat, its contractions may be re-excited by stimulating the roots of the Spinal Accessory nerve, or of the first four Cervical nerves; the influence of that stimulation being conveyed to the heart by the Sympathetic system, the cardiac portion of which communicates with these nerves. Irritation of the Par Vagum, also, has a tendency to accelerate the heart's action, or to re-excite it when it has ceased; but the complete severance of both its trunks produces little disturbance in the regularity of the movement. The action of the heart may be also affected more directly through the sympathetic system; thus it is excited by irritation of the cervical ganglia, especially the first; whilst continued pressure upon the cardiac nerve, by an enlarged bronchial gland, has appeared to be the cause of its occasional suspension. It is without doubt through its nervous connections, and probably though the sympathetic system, that the heart receives the influence of mental emotions.

581. The movements of the heart may be suspended, or altogether checked, by sudden and violent impressions on the nervous centres, even though these do not occasion any perceptible breach of substance. Thus in *concussion* of the brain, there is not merely insensibility, but also a complete suspension of the circulation, occasioned by a failure of the heart's power. This suspension may be permanent, so that animation cannot be restored; or it may be temporary, as in ordinary fainting. The well-known influence of blows upon the epigastrium, in producing sudden death, is probably to be attributed to a similar cause,—namely, the shock thus communicated to the extensive plexus of ganglionic nerves, radiating from the semilunar ganglia, and proceeding to the abdominal viscera. Violent impressions upon other nervous expansions may produce a dangerous weakening of the heart's contractile power; this is the case, for example, with extensive burns, which may produce faintness, and even death, especially

in children, by the depression which they induce. Many other causes of sudden suspension of the heart's action might be enumerated ; but they may be generally traced to a strong impression upon the nervous system ; though of the mode in which this operates we know nothing.

4. *Movement of the Blood in the Arteries.*

582. The Blood, thus propelled from the Heart into the Arteries by a series of interrupted jets, would continue to flow in the same manner, if it were not for the equalization of its movement, effected by the properties of the arterial walls. This influence is exerted by the middle or fibrous coat, which consists in part of yellow elastic tissue (§ 189), and in part of non-striated muscular fibre (§ 337). The proportion of these two components varies in arteries of different calibre; the muscular tissue being thicker in the smaller branches, and the elastic tissue being found in larger amount in the main trunks.

583. It is chiefly to the simple physical property of *Elasticity*, thus possessed by the Arterial tubes, that we owe the equalization of the flow of blood; and we may hence understand the reason, why the trunks that are in nearest connection with the heart, should be those most endowed with it. If a forcing-pump were to inject water, by successive strokes, into a system of tubes with perfectly unyielding walls, the flow of fluid at the farther extremities of these tubes would be as much interrupted, as its entrance into them. But if the pump be connected with an air-vessel (as in the common fire-engine), so that a part of the force of each stroke is expended in compressing the air, the expansion of this, during the interval between the successive strokes, produces a continuous flow of water along the tubes. Or if the tubes themselves were endowed with a certain degree of elasticity, which should allow them to dilate near their commencement, so as to receive the new charge of fluid, and which should occasion a continued pressure upon the fluid during the intervals of the stroke, the same equalizing effect would be produced. This is precisely the case with the Arterial system; the intermittent jets, by which the blood is propelled from the heart, are speedily converted into a continued stream ; so that, at even a moderate distance from the heart, the only indication of its interrupted action is presented by the greater or less rapidity of the flow; and this gives rise, when an artery is divided, to an alternate rise and fall of the jet of blood, and, in the ordinary circulation, to the phenomenon called the *pulse*. This is due to an increase in the dimensions of the arterial tube, both in length and breadth, with each additional ingress of blood ; the increase in length is the more considerable of the two effects, and causes the artery to be somewhat lifted from its seat. During the intervals, a quantity of blood corresponding to that which had entered, escapes by the further extremity of the tube; and thus the artery is enabled to contract to its previous dimensions, and to return to its bed. We

may compare the pulse, therefore, to a wave, which commences in the heart, and travels onwards through the arterial system.

584. In the large arteries near the heart, the pulsation is always precisely synchronous with the ventricular systole; but it takes place somewhat later in the arteries at a distance from the heart; the time required for the transmission of the wave being proportioned to the degree in which the walls of the arteries yield to it. If they were *quite* rigid, the egress at one extremity must take place at the precise moment that the fluid is forced into the other. On the other hand, if the walls be too easily distensible, they yield to the propelling force in such a degree that it is entirely expended upon them; and the fluid is not moved onwards at all, or but very slowly. In the healthy state of the arterial walls, they should contract upon their contents, with sufficient force to equalize the flow of blood, and to prevent the pulse-wave from occupying more than one-sixth or one-seventh of a second, in its propagation to the remotest arteries of the system; and the pulse should be full, producing a prolonged but gentle elevation beneath the finger, and capable of resisting moderate pressure. This condition is dependent in great part upon the due *tonicity* of the muscular coat of the arteries (§ 365). When this tonicity is in excess, the walls of the arteries are too rigid; the pulse at the wrist is felt to occur exactly at the same time with the ventricular systole; and its character is that of strength, incompressibility, and sustained power, though it may be even slower than usual. This is the case in what is commonly termed "high condition" of the system; which predisposes to inflammatory disorders, but which renders it less susceptible than usual to the influence of malaria, contagious miasmata, or other causes of a depressing character. On the other hand, when the tonicity of the arteries is less than it should be, their walls yield too much to the pulse-wave; so that the pulse at the wrist is often felt even after the *second* sound is heard; and the pulse itself is jerking, unsteady, and too easily compressible. This loose relaxed state of the vessels is the most unfavourable that can be to regularity and vigour of the circulation; and it manifests its ill effects in the general condition of the system, which is then peculiarly prone to suffer from the agency of malaria, infectious miasmata, or any other depressing causes.

585. Although many Physiologists have denied that the Arteries possess real Muscular Contractility in any degree, yet there can be no longer any doubt on the subject; since numerous experimenters have succeeded in producing distinct contraction in their walls, by the application of those stimuli which act upon muscular fibre in general. Moreover it has been ascertained, that when an artery is dilated by the blood injected into it from the heart, it reacts with a force superior to the impulse to which it yielded; and that, if a portion of an artery from an animal recently dead, in which the vital properties are still preserved, and a similar portion from an animal that has been dead some days, in which nothing but the elasticity remains, be distended with equal force, the former contracts to a much greater degree than

the latter, after the distending force is withdrawn.—One use of this contractile power may very probably be, to assist the Heart in maintaining the flow of blood; for if the Arterial walls yield readily to the ingress of blood, and then contract upon their contents with a force greater than that which distended them, the current must necessarily be propelled onwards with greater force. This supplementary propelling force, on the part of the arteries, may serve as a compensation to that diminution of the heart's power, which must result from the increased friction of the blood against the walls of the vessels occasioned by their subdivision; and we thus observe, even in the highest animals, some traces of that diffused agency, on which the Circulation is so much more dependent in the lower tribes.

586. It seems probable, however, that one chief use of the Muscularity of the Arterial walls consists in its regulation of the diameter of the tubes, in accordance with the quantity of blood to be conducted through them to any part; the proper amount being determined by circumstances at the time. Such local changes may form a part of the regular series of actions of the human body, as when the Uterine and Mammary arteries undergo enlargement, at the periods of pregnancy and parturition; and they occur still more frequently in diseases, which are attended by increased action of particular organs. In such cases, it cannot be *vis a tergo* of the Heart, that occasions the enlargement of certain arterial trunks, and of no others; since any increase in its propulsive power would affect all alike. It must be, therefore, through a power inherent in themselves, that the dilatation takes place; and there seems much reason for attributing to the Sympathetic system of nerves a control over this power, and consequently the office of regulating the local distribution of blood, in accordance with the wants of the different parts. It is well known that the nerves of this system are copiously distributed upon the arterial walls; and it has been experimentally shown, that they have the power of producing contractions in the larger arteries. Moreover, there is every reason to believe, that the diameter of the Capillary blood-vessels, and the rate of the movement of blood through them, are much influenced by these nerves (§ 603); and it seems highly probable, therefore, that they should have a corresponding influence upon the size of the trunks, from which these capillaries are derived.

587. The Arterial system possesses nearly the same relative capacity in every part: that is, if a section could be made through *all* the systemic arteries at a certain distance from the heart, the united areas would be found equal to that of the aorta; and those of the branches of the pulmonary arteries would equal those of their trunk. This results from the fact, that, at every subdivision, the united *areas* of the branches are almost precisely equal to that of the trunk from which they proceeded; although the united *diameters* of the former far exceed that of the latter. According to a well-known mathematical law, the areas of circles are as the squares of the diameters; con-

sequently, in making such comparisons, it is necessary to square the diameters of the trunk and those of the branches, and to contrast the former with the sum of the latter. Thus a trunk whose diameter is 7, may subdivide into two branches, each having a diameter of nearly 5; for the square of 7 is 49, and twice the square of 5 is 50. Or a trunk whose diameter is 17 may subdivide into three branches, whose diameters are 10, 10, and $9\frac{1}{2}$ (making $29\frac{1}{2}$ as the sum of the *diameters*); for the square of the diameter of the trunk is 289, whilst the sum of the squares of those of the branches is $290\frac{1}{4}$. It appears from Mr. Paget's recent admeasurements, that there is seldom an exact equality between the area of the trunk and that of its branches; the area sometimes increasing, and sometimes diminishing. The former seems the general rule in the upper extremities; the latter in the lower. Thus the area of the trunk of the external carotid is to that of its branches, as 100 to 119; whilst the area of the abdominal aorta, just before its final division, is to that of its branches as 100 to 89.

588. In almost every part of their course, the ramifications of the arteries communicate freely with each other, by *anastomosis;* and this communication is most important, as affording the means by which the circulation is sustained, when the current through the main trunk is obstructed. There is scarcely an artery in the body, except the aorta, which may not be tied, with the certainty that the blood will still be conducted to its destination, by the collateral circulation. At first, the quantity which thus passes is very insignificant, and is by no means sufficient to supply what is needed; thus, when the femoral artery has been tied for popliteal aneurism, the limb becomes cold, and the sensibility of its surface and its muscular power are alike diminished. In a few hours, however, its warmth returns, and its sensibility and muscular power are restored; indicating that its circulation has been already re-established through the collateral branches. And where an opportunity presents itself at a subsequent period for examining the state of the vessels in such a limb, it is found that an extraordinary enlargement has taken place in arteries that were previously of insignificant size, which form a communication between the branches that issued above and below the interruption. Moreover, it is commonly found, that the main trunk has become completely impervious above the part where it was obliterated by the ligature, up to the point at which the nearest lateral branch is given off.—Even the abdominal aorta has been tied in dogs, without fatal results; the circulation in the posterior part of the body, and in the hinder extremities, being then maintained chiefly by the inosculation of the external mammary artery with the epigastric, upon the parietes of the abdomen.

5. *Movement of Blood in the Capillaries.*

589. The ultimate ramifications of the Arteries pass so insensibly into those of the Veins, that no definite line of demarkation between

them can be drawn; and although we are in the habit of speaking of the "Capillaries" as a distinct system of vessels, yet it ought to be strictly borne in mind, that they differ only in size from the vessels, from which they receive their blood on the one side, and into which they pour it on the other. It was at one time supposed that they are merely channels or passages, excavated in the tissues, having no definite walls of their own. This is probably true of them in the lower tribes of Animals; and it may also be the case at an early stage of their development in the higher. But when their formation is complete, they undoubtedly possess walls of a fibrous texture, as distinct as those of the arteries and veins, though of extreme thinness. From the occasional appearance of bodies resembling cell-nuclei, in the substance of the walls of the capillaries, it has been thought that their tubes are formed, in the first instance, by the coalescence of cells arranged in a linear direction; and this idea receives confirmation from the fact, that the ducts of Plants are undoubtedly formed in this manner, and not by the mere retirement of the tissues on either side leaving an intervening channel. The closely-reticulated structure usually formed by the capillaries, has commonly been regarded as distinguishing them both from the arteries and the veins; and it is not uncommon to speak of the arteries as delivering the blood into the "capillary network," and the veins as receiving the fluid that has traversed this. Such expressions are not incorrect as implying the simple fact, that between the arteries and the veins is a network of minute vessels, through which the blood has to travel when proceeding from one to the other; but these vessels must not be regarded as belonging to a distinct class, being nothing else than the minutest subdivisions of the veins and arteries, which commonly inosculate freely with each other.

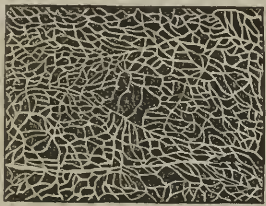
590. The degree of this inosculation, and the consequent form of the capillary network, are subject, however, to very great variations; and these may be generally shown to have a relation to the form of the ultimate elements of the tissues, which are traversed by the capillaries. Thus we see in the capillaries of Muscle, that the major part run parallel to the course of the fibres, lying in the minute interspaces between them (Fig. 88); a few transverse branches serving to connect them with each other. A similar distribution prevails in the capillaries of the Nervous trunks; but those of the Nervous centres are arranged in the form of a minute network, so as completely to traverse every part of the structure (Fig. 89). Again, we observe that the capillaries of Glands form a minute network around the secreting follicles (Fig. 90); and a similar arrangement prevails in the capillaries of the air-cells of the lungs, which are set so closely together, that it would seem as if the purpose

Fig. 88.

Capillary network of Muscle.

were to cover the surface with blood as completely as possible, consistently with its being retained within vessels, and not spread out

Fig. 89.



Capillary Network of Nervous Centres.

Fig. 90.

Capillary Network around the follicles of Parotid Gland.

into a continuous film (Fig. 102). A network of very much the same character is found in the villi of the mucous membrane (Fig. 77), on the ordinary surface of simple mucous membrane (Fig. 91), and on

Fig. 91.

Capillary Network in simple mucous membrane of palpebral conjunctiva.

Fig. 92.

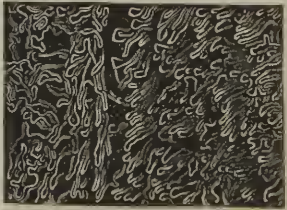
Capillary Network in choroid coat of the eye.

that of the choroid coat of the eye (Fig. 92). Where the surface of the mucous membrane is depressed into follicles, the arrangement of the capillaries has an evident reference to these (Fig. 93); whilst, on

Fig. 93.

Distribution of Capillaries around follicles of Mucous Membrane.

Fig. 94.



Distribution of Capillaries at the surface of the skin of the finger.

the other hand, where the surface of the skin is raised up into sensory papillæ, the capillary network sends looped prolongations into these, which are found accompanying their nerves (Figs. 94 and 95.)

Fig. 95.

Capillary Network of fungiform papilla of the tongue.

591. It cannot be supposed that the arrangement of the vessels has any further influence upon the function of the part they supply, than that which it derives from the regulation of the supply of blood afforded to each individual portion of the structure. The form of the capillary network is evidently determined by that of the elements of the tissues permeated by it; *these* are the real operative instruments in every part; and the distribution of the blood-vessels is so arranged, as to afford them precisely the amount of nourishment they respectively require. Thus we have seen, that there are many living parts, possessing most important functions, in the human body, which are not in any direct relation with blood-vessels, and which yet derive their whole nutriment, and the materials of their functional operations, from the blood. This is the case, for example, with the whole of epithelial and epidermic cells; and also with the articular cartilages, and the substance of the teeth. Even in bone, the islets between the Haversian canals, which are completely unpenetrated by vessels, are of considerable size. Such islets must everywhere exist, between the meshes of the capillary network; so that the question of the vascularity or non-vascularity of a tissue is one of *degree* only;—the ultimate fibre of muscle or nerve, and the cells and fibres of other tissues, being as completely non-vascular, as the entire substance of a tooth or of an articular cartilage; the latter being nourished, like the former, by imbibition from the surrounding vessels.

592. The term "Capillary" may be employed in an extended or a restricted sense; in the former it includes *all* the minute vessels, which pass between the arteries and the veins; in the latter it is applied only to those, which admit no more than a single file of blood-discs at once, and excludes those, which admit two, three, or even four rows, even although they establish a direct communication from one side of the network to the other. The former application of the term is the most convenient, although perhaps not the most strictly accurate; and it will be therefore here employed in its extended sense. And this is rendered more correct by the fact, that the size of the individual capillaries is by no means permanent; an enlargement often taking place in one, and a contraction in others, at the same time: so that vessels, which were previously true capillaries, no longer remain such; and passages, which were previously of far greater calibre, are reduced to the average diameter.

593. The opinion was long entertained, that there are vessels adapted to the supply of the white or colourless tissues; carrying

from the arteries only the fluid portion of the blood, or *liquor sanguinis*, and leaving the rest behind. No other such vessels have been really observed, however, than capillaries in a state of unusual contraction, as just now mentioned. And it may be safely affirmed, that the supposition of their existence is not required. For any one who observes the smallest capillary vessels under the microscope, may perceive, that the current of blood which passes through them is almost free from colour,—as the red corpuscles themselves appear to be, when spread out in a single layer. Tissues which are rather scantily permeated by such vessels, therefore, may still be white; and it is only where the network is very close, and the quantity of blood which passes through it is consequently great, that a perceptible colour will be communicated by the red corpuscles. And we have seen, that the idea that Nutrition can only be carried on by direct communication with vessels, is entirely unfounded; the tissues into which no blood-vessels can be traced, being adapted to nourish themselves, like cellular Plants, by the imbibition of fluid at their surfaces, on which vessels are (for the most part) copiously distributed.

594. That the blood can only minister to the operations of Nutrition, Secretion, &c., whilst it is circulating through the Capillaries, is evident from several considerations. The thickness of the walls of the larger vessels interposes an effectual barrier to its transudation; and so completely is the blood cut off, even from penetrating these, that they do not derive their own nourishment from the blood which flows in their own tubes, but from a capillary network in their own substance, which is supplied by vessels from collateral branches,—these being termed the *vasa vasorum*. Moreover it is by the inosculation of the capillaries alone, that the minute network is formed, which serves to bring the blood into proximity with the minute parts of the tissues to be nourished; thus let it be supposed that the minute arteries of Muscle were to terminate in veins, without undergoing further subdivision, the *islets* left between their anastomosing branches would be far too large, and the nutritive materials would consequently not be supplied with sufficient readiness, even supposing that it could freely permeate the walls of these vessels.—The Capillaries, then, must not be regarded as altogether distinct in their endowments, from the vessels with which they are connected on either side; but merely as intended, by their minute subdivision and inosculation, to bring the blood into sufficiently close relation with the tissues they are to nourish, and to allow a greater degree of transudation of its elements by the comparative thinness of their walls.

595. When the flow of blood through the capillaries of a transparent part, such as the web of a Frog's foot, is observed with the microscope, it appears at first to take place with great evenness and regularity. The influence of the contractions of the heart may be seen to extend itself into the smaller arteries; the blood moving onwards in them with a somewhat jerking motion. But this influence altogether disappears in the Capillary network; the flow of blood

through this being even and continuous, except when the action of the heart is becoming weak and irregular, or when its influence is impeded by obstruction in the vessels leading to the part,—the blood being then impelled by a succession of jerks, with intervals of complete repose.—But on watching the movement for some time, various changes may be observed, which cannot be attributed to the heart's influence, and which show that a certain regulating or distributive power exists in the walls of the capillaries, or in the tissues which they traverse. Not only do we occasionally perceive some of the tubes enlarging, so as to admit several files of blood-discs instead of one, whilst others that previously received several, now only admit one;—but we also see vessels coming into view, which were not previously noticed, whilst other vessels seem to become obliterated. This apparently new formation and obliteration of vessels, however, do not really take place; for a more close examination shows, that the former of these appearances is due to the entrance of red corpuscles into passages, which existed before, but which were in such a state of contraction as enabled them only to admit the fluid portion of the blood; whilst, by a converse change in certain capillaries, from the dilated to the contracted state, the appearance of obliteration is produced, the red corpuscles being excluded, and the transparent fluid of the blood being alone transmitted by them.

596. But these are by no means all the irregularities, which may be detected by a close scrutiny of the Capillary circulation. The velocity of the current is liable to great and sudden variations, which cannot be accounted for by any change in the heart's action, or in the supply of blood afforded by the arteries; and this change may manifest itself, either in the whole capillary network of a part, or in a portion of it,—the circulation taking place with diminished rapidity in one part, and with increased energy in another, though both are supplied by the same trunk. These variations are sometimes manifested by the complete change in the direction of the movement, in certain of the transverse or communicating branches; this movement taking place, of course, from the stronger towards the weaker current. Not unfrequently an entire stagnation, of longer or shorter duration, precedes the reversal of the direction. Irregularities of this kind are most frequent, when the heart's action is enfeebled or partially interrupted; and it would thus appear, that the local influences by which they are produced, are overcome by the propelling power of the central organ, when this is acting with its full vigour. When the whole current has nearly stagnated, and a fresh impulse from the heart renews it, the movement is seldom uniform through the entire plexus supplied by one trunk; but is much greater in some of the tubes than in others,—the variation being in no degree connected with their size, and being very different in its amount at short intervals.

597. All these circumstances indicate that the movement of blood through the Capillaries is very much *influenced* by local forces; although these forces are not sufficiently powerful, in the higher ani-

mals, to *maintain* it alone. And from other facts it appears, that the conditions necessary for the energetic flow of blood through these vessels, are nothing else than the active performance of the nutritive and other operations, to which they are subservient. The examination of a single one of these processes, will afford us the requisite proof. The blood when circulating through the *systemic* capillaries, yields a portion of its oxygen to the tissues it permeates, and receives from them carbonic acid. On the other hand, when passing through the *pulmonary* capillaries, it gives up its carbonic acid to the atmosphere, and imbibes a fresh supply of oxygen. Now if either of these changes be prevented from taking place, a retardation and even a complete stagnation, of the blood will take place,—the flow through the capillaries being now resisted, instead of accelerated, by the relation which the blood bears to the tissues. Thus it has been shown, that if an animal be partially deprived of oxygen, so that the arterial blood is not duly aërated (rather resembling the ordinary venous blood), and cannot exert its proper action on the tissues, the pressure upon the walls of the systemic arteries is *increased*, although the supply of blood propelled by the heart, and the propulsive power of the heart itself, are *diminished;* and this plainly indicates a retardation in the systemic capillaries, producing an undue accumulation in the arteries.—On the other hand, the suspension of the supply of oxygen to the lungs, either by an obstruction in the air-passages, or by causing the animal to breathe some other gas, brings the pulmonary circulation to a stand in a very short time, the blood not being able to undergo its usual changes in the capillaries of those organs; and by this stagnation, the whole movement of blood is speedily checked. The readmission of oxygen, if the suspension of the circulation have not been too long continued, occasions the renewal of the movement in the capillaries, and thence in the whole circle of vessels; and this even after the heart has ceased to propel blood towards the lungs.

598. The principles already noticed (§ 547), as put forth by Prof. Draper, seem fully adequate to explain these phenomena. The arterial blood,—containing oxygen with which it is ready to part, and being prepared to receive in exchange the carbonic acid which the tissues set free,—must obviously have a greater affinity for the tissues, than venous blood, in which both these changes have already been effected. Consequently, upon mere physical principles, the arterial blood, which enters the systemic capillaries on one side, must drive before it, and expel on the other side of the network, the blood which has become venous whilst traversing it. But if the blood which enters the capillaries have no such affinity, no such motor power can be developed. On the other hand, in the capillaries of the lungs, the opposite affinities prevail. The venous blood and the air in the pulmonary cells have a mutual attraction, which is satisfied by the exchange of oxygen and carbonic acid that takes place through the walls of the capillaries; and when the blood has become arterialized, it no longer has any attraction for the air. Upon the very same prin-

ciple, therefore, the venous blood will drive the arterial before it, in the pulmonary capillaries, whilst respiration is properly going on: but if the supply of oxygen be interrupted, so that the blood is no longer aërated, no change in the affinities takes place whilst it traverses the capillary network; the blood, continuing venous, still retains its need of a change and its attraction for the walls of the capillaries; and its egress into the pulmonary veins is thus resisted, rather than aided, by the force generated in the lungs.

599. The change in the condition of the blood, in regard to the relative proportions of its oxygen and carbonic acid, is the only one to which the Pulmonary circulation is subservient; but in the Systemic circulation, the changes are of a much more complex nature,—every distinct organ attracting to itself the peculiar substances, which it requires as the materials of its own nutrition, and the nature of the affinities thus generated being consequently different in each case. But the same law holds good in all instances. Thus the blood conveyed to the liver by the portal vein, contains the materials at the expense of which the bile-secreting cells are developed; consequently the tissue of the liver, which is principally made up of these cells, possesses a certain degree of affinity or attraction for blood containing these materials; and this is diminished, so soon as they have been drawn from it into the cells around. Consequently the blood of the portal vein will drive before it, into the hepatic vein, the blood which has traversed the capillaries of the portal system, and which has given up, in doing so, the elements of bile to the solid tissues of the liver. —The same principle holds good in every other case.

600. We are now prepared, therefore, to understand the general principle, that the rapidity of the circulation of a part will depend in great measure upon the activity of the functional changes taking place in it,—the heart's action, and the state of the *general* circulation, remaining the same. When, by the heightened vitality, or the unusual exercise, of a part, the changes which the blood naturally undergoes in it are increased in amount, the affinities which draw the arterial blood into the capillaries are stronger, and are more speedily satisfied, and the venous blood is therefore driven out with increased energy. Thus a larger quantity of blood will pass through the capillaries of the part in a given time, without any enlargement of their calibre, and even though it be somewhat diminished; but the size of the arteries by which it is supplied, soon undergoes an increase, which adapts it to supply the increased demand. Any circumstance, then, which increases the functional energy of a part, or stimulates it to increased nutrition, will occasion an increase in the supply of blood, altogether irrespectively of any change in the heart's action. This principle has long been known, and has been expressed in the concise adage "Ubi stimulus, ibi fluxus;" which those Physiologists, who maintain that the Circulation is maintained and governed by the heart alone, cast into unmerited neglect.

601. An undue acceleration of the local circulation, arising from an

excess of functional activity in the part, and unaccompanied by any other change, constitutes the state known as *active congestion*, or *determination of blood*. This may be artificially produced by the application of gentle stimulants; and it is usually the first change that occurs, when their action proves sufficiently violent to produce inflammation. From that state, however, it is distinguished by this important character,—that there is merely an *exaltation* of the *natural* function, but *no change*. Moreover we shall presently see that, in Inflammation, there is a stagnation of blood, not an acceleration. We frequently meet with cases, in which this active congestion becomes very manifest; especially in persons of active minds, who exert their mental powers too violently, and who thereby induce an habitually increased flow of blood towards the head, manifested in the increased pulsation of the carotids, the suffusion of the face and eyes, and the heat of the surface. The balance of the circulation being thus disturbed, there is almost invariably a diminished energy of the movement of blood in other organs, especially the extremities; as indicated by their habitual coldness and lividity. In the treatment of such a state (which is often the precursor of serious disease), it should be our object to restore the circulation in the extremities, by friction, exercise, &c.; and to abate the flow of blood towards the head, by restraining the functional activity of the brain, by the application of cold to the surface, by keeping the head high during sleep, and other means of similar tendency.

602. There is another condition of the capillary circulation, also known under the name of *Congestion*, which is precisely the opposite of the preceding. In this state, there is deficient functional energy in the part and the circulation through it is consequently retarded,—as in the lungs, when there is a partial obstruction to the aëration of the blood. The same cause produces a deficient tonicity of the Arteries, and allows their walls to be unduly distended by the *vis a tergo* of the blood; and consequently there is a great accumulation of blood in the part with a retarded movement. This condition, like the preceding, predisposes to Inflammation, although in a different mode, as will be explained hereafter (§ 631). It is relieved by causes which promote the action of the part; thus congestion of the lungs, occasioned by the effusion of fluid into the air-cells, which creates an obstacle to the aëration of the blood disappears, when that effusion is absorbed. And congestion of the liver, the result of deficient secreting power in the organ, is relieved by mercurial and other medicines, which promote the flow of bile by stimulating the growth of the hepatic cells.

603. The Capillaries, like the Arteries, possess a power of contraction and dilatation which seems to be very much under the influence of the Nervous System, and particularly of that part of it which conveys the influence of the Emotions. We have a *visible* example of this influence, in the act of *Blushing;* which consists in a sudden enlargement of the capillaries and small vessels of the surface; whilst the converse state of *pallor*, which often alternates with it under the

influence of strong emotion, is evidently due to an unusual contraction of the same vessels. But the effects of this influence are no less sensible in other cases; and particularly in the regulation of the quantity of certain secretions, in accordance with the mental state, or the condition of the system generally. To the mode in which this regulation is effected, the act of blushing seems to afford us the key; for it indicates that the supply of blood afforded to the glands, may be entirely governed by the influence of the nervous system upon the calibre of the arteries. Thus, the nursing mother, at the sight, or even at the thought of her child, when the usual time for suckling approaches, feels a rush of blood to the breast, exactly resembling that which takes place to the cheeks in blushing, and popularly termed "the draught;" this rush occasions an almost immediate increase in the secretion. In like manner we may explain the influence of the mental state upon the *amount* of the secretions of the lachrymal, the salivary and many other glands; its influence upon their *quality*, must probably be effected through changes in the condition of the blood itself.

604. The supply of Nervous agency from the Cerebro-spinal system has been clearly proved to exert no direct influence in maintaining the capillary circulation; since the latter continues as usual, after all the nerves of a part have been divided. This is obviously due to the fact, that the operations of nutrition, secretion, &c., are essentially independent of this agency. But as *they* are in some degree *influenced* by it, so will the capillary circulation be affected through its connection with them. In this manner we are to explain the effect of violent impressions upon the nervous centres in bringing to a stand, not merely the action of the heart (§ 581), but the Capillary circulation all over the body. The general vitality of the system appears to be at once destroyed; so that the capillary circulation, which may usually be seen to continue in the web of a frog's foot for some time after the interruption of the heart's action, is immediately suspended by crushing the brain with a hammer.

6. *Of the movement of Blood in the Veins.*

605. The Venous system is formed by the reunion of the small trunks which originate in the Capillary network; and it carries back to the heart the blood which has been transmitted through this. This blood is *dark* or carbonated in the *systemic* veins; whilst it is *bright* or oxygenated in the pulmonary veins.—The structure of the veins is essentially the same with that of the arteries; but the fibrous tissue of their middle coat less decidedly exhibits the characters, either of the yellow elastic tissue, or of non-striated muscle. Still it possesses no inconsiderable amount of Elasticity; and a certain degree of muscular Contractility also. The whole capacity of the Venous system is at least *twice*, and perhaps more nearly *three times*, that of the Arterial; and the rate of motion of the blood in them must be proportionably slower.

606. The movement of the Blood through the Veins is, without doubt, chiefly effected by the *vis a tergo*, or propulsive force, which results from the contractile power of the heart and arteries, aided by the power generated in the capillary vessels. The intermittent flow, which is caused by the interrupted action of the former is usually so far equalized during the passage of the blood through the capillary network, that no pulsation can be shown to exist in the veins; but instances occasionally present themselves, in which a venous pulse may be clearly perceived.—The Venous Circulation is affected, however, by certain other causes which exert little influence on the movement of blood in the Arteries. One of these is the frequently recurring action of Muscles, to which the Veins are peculiarly subject, on account of their position. In every instance in which Muscular movement takes place, a portion of the Veins of the part will undergo compression; and as the blood is prevented by the valves in the veins, from being driven back into the small vessels, it is necessarily forced onwards towards the heart. As each set of muscles is relaxed, the veins that were compressed by it fill out again, to be again compressed on the renewal of the force. Thus, we see how the general Muscular movements of the body have an important influence, in maintaining the Venous Circulation,—how continued exercise, involving the alternate contraction and relaxation of several groups of Muscles, must send the blood more rapidly towards the heart, and thus increase the rapidity of its pulsations,—and how the sudden and simultaneous action of a large number of muscles after repose (as when we rise up from the sitting or lying to the standing posture), may drive the blood to the heart with so violent an impetus as to produce even fatal results, if, by any diseased condition of that organ, it should be rendered unable to dispose with sufficient rapidity, of the quantity of blood thus driven to it.

607. The Respiratory movements exert a slight influence upon the flow of blood through the large veins near the heart; for as the chest is a closed cavity, in which a partial vacuum is produced by the act of Inspiration, whilst its contents are compressed by the act of Expiration, the former state will favour the movement of blood from the large veins on the exterior of the cavity, towards the heart, whilst the latter condition will retard it. This produces the phenomenon termed the *respiratory pulse;* which may be seen in the veins of the neck and shoulders in thin persons, and especially in those who are suffering from pulmonary diseases. The influence of the Respiratory movements is made evident by introducing a tube into the Jugular vein, the lower end of which dips into water; for an alternate elevation and depression of the water in the tube are then witnessed, showing the suction power of the Inspiratory movement, and the expellent force of the Expiratory act. On the other hand, the Expiratory movement, while it directly tends to cause accumulation in the veins, will assist the heart in propelling the blood in the Arteries; and by the combined action of these two causes are produced, among other effects,

the rising and sinking of the Brain, synchronously with expiration and inspiration, which are observed when a portion of the cranium is removed.

608. A pulsatory movement may be occasioned in the great veins near the heart, by another cause entirely distinct from the preceding;—namely, the regurgitation of blood from the ventricle into the auricle, and thence into the venæ cavæ, during the *ventricular* systole; and the pulsation thus occasioned is synchronous, therefore, with that in the arteries (proceeding *backwards*, however, from the heart), instead of corresponding with the respiratory movement. This regurgitation may take place, not from any disease in the valves on the right side of the heart, but simply from over-distension of its cavities, resulting from any obstruction to the circulation of blood through the lungs, for when this occurs, the tricuspid valve does not completely close, and allows a portion of the blood to escape from the ventricle backwards into the auricle and vena cava. This want of complete closure, effecting what has been termed the "safety-valve function" of the tricuspid valve, has been particularly noticed in diving animals, in which the circulation through the lungs is liable to be temporarily suspended. The venous pulsation which is thus produced may be noticed in almost every case of long-standing dyspnœa; especially when this is accompanied (as it usually is) by hypertrophy and dilatation of the right ventricle of the heart.

609. The Venous circulation is much more liable than the Arterial, to be influenced by the force of Gravity; and this influence is particularly noticeable, when the tonicity of the vessels is deficient. The following experiments performed by Dr. Williams, to elucidate the influence of deficient firmness in the walls of the vessels, and of gravitation, over the movement of fluids through tubes, throw great light on the causes of Venous Congestion. A tube with two equal arms having been fitted to a syringe, a brass tube two feet long, having several right angles in its course, was adapted to one of them, whilst to the other was tied a portion of a rabbit's intestine four feet long, and of calibre double that of the brass tube, this being arranged in curves and coils, but without angles and crossings. When the two ends were raised to the same height, the small metal tube discharged from two to five times the quantity of water discharged in a given time by the larger but membranous tube; the difference being greatest, when the strokes of the piston were most forcible and sudden, by which the intestine was much dilated at its syringe end, but conveyed very little more water. When the discharging ends were raised a few inches higher, the difference increased considerably, the amount of fluid discharged by the gut being much diminished; and when the ends were raised to the height of eight or ten inches, the gut ceased to discharge, each stroke only moving the column of water in it, and this subsiding again, without rising high enough to overflow. When the force of the stroke was increased, the part of the intestine nearest the syringe burst.

610. From these experiments it is easy to understand, how any deficiency of tone in the Venous system will tend to prevent the ascent of the blood from the depending parts of the body, and will consequently occasion an increased pressure on the walls of the vessels, and an augmentation in the quantity of blood they contain. All these conditions are peculiarly favourable to the escape of the watery part of the blood from the small vessels; and this may either infiltrate into the areolar tissue, or it may be poured into some neighbouring serous cavity, producing dropsy. Thus it happens, that such effusions may often be traced to that state of deficient vigour of the system, which peculiarly manifests itself in want of tone of the blood-vessels; and that it is relieved by remedies which tend to restore this. In many young females of leucophlegmatic temperament, for example, there is a tendency to swelling of the feet, by œdematous effusion into the areolar tissue, in consequence of the depending position of the limbs; the œdema disappears during the night, but returns during the day, and is at its maximum in the evening. And the congestion which frequently manifests itself in the posterior parts of the body, towards the close of exhausting diseases, in which the patient has lain much upon his back, is attributable to a similar cause; of such congestion, effusions into the various serous cavities are frequent results; and such effusions taking place during the last hours of life, are often erroneously regarded as the cause of death. To the same cause we are to attribute the varicose state of the veins of the leg, which is so common amongst persons of relaxed fibre, and especially in those whose habits require them to be much in the erect posture; and this distension occasionally proceeds to complete rupture, the causes of which are fully elucidated by the experiments just cited.

611. It has been thought that the circulation within the Cranium takes place under different conditions from that of other parts of the body. For as the cranium is a closed cavity,—a certain part of which is occupied by the cerebral substance and its membranes, the remainder being filled up with blood,—it has been argued that the amount of blood in the vessels of the brain must be always the same; and that any disturbance of its circulation must be due to a difference in the relative quantity of blood in the arteries and the veins. This idea appeared to derive support from the results of experiments; which showed that the blood is retained in the vessels within the cranium of animals bled to death, unless an opening be made in the skull, so as to allow the air to exert the same pressure upon these vessels, as upon those of other parts. But such experiments do not at all sanction the assertion, that the quantity of blood within the cranium is constant; on the contrary, we have reason to believe that it undergoes as much change as in other parts. For although the cerebral substance be incompressible, yet its bulk is subject to constant variation, according to the quantity of fluid it contains; and the presence of the cerebro-spinal fluid in the sub-arachnoid cavity in the brain and spinal cord, appears to be peculiarly destined to favour this

continual change,—the proportions of it contained in the spinal and cerebral cavities, respectively, being governed by the bulk of the other contents of the cranium. Thus if the vessels of the cerebrum be in their ordinary state of fullness, a certain amount of fluid is present in the sub-arachnoid cavity of the brain; this will be pressed out into the spinal portion of the cavity, if the cerebral vessels be unusually distended with blood; whilst it will be increased from the latter source, so as to fill up the vacant space within the cranium, if the cerebral vessels be unusually empty.

CHAPTER VII.

OF NUTRITION.

1. *Selecting power of the Individual Parts.*

612. The Blood, which is carried into the different parts of the system, by the Circulating apparatus, is the source from which all the organs and tissues of the body derive the materials of their growth and development; and, as we have seen, it is distributed by the Capillaries of the several tissues, with a degree of minuteness, which varies according to the activity of the nutrient operations taking place in the individual parts. Thus, in Nerve and Muscle, Mucous Membrane, and Skin, a constant decay of the old, and development of new tissue, are taking place, when these organs are in a state of functional activity; and a copious supply of blood is carried through every part of their substance: whilst in Cartilage and Bone, Tendon and Ligament, the amount of interchange is very small, and is effected by a much less minute reticulation of capillary blood-vessels.

613. The *materials* of the nutritive process being prepared in the blood, the process of Nutrition is the act of each individual part; which grows and develops itself, in virtue of its own inherent powers, as long as the requisite conditions are supplied. The mode in which this takes place, in each individual tissue, has been already explained in the former part of this Treatise. We have seen that, in the great majority of cases, the act of Nutrition is, in fact, a process of cell-growth; and that it takes place under the same conditions, as the production of the simple isolated cell, which constitutes the whole of the humblest forms of Cryptogamic Vegetation,—namely, that it grows from a germ, which draws to itself the materials of its nutrition, and gives to some of them a new arrangement, whereby they form the cell-wall, whilst others are introduced into the cell-cavity,—and that, when it has passed through its regular series of changes, it dies, and sets free its contents. We have seen that, in

some cases, the germs are prepared by previously existing cells of the same kind; whilst in others they are furnished by certain "nutritive centres," which seem to be constantly engaged in the preparation of them, deriving their materials from the blood. Frequently it would seem as if the original or parent-cell was able to continue the production of secondary cells to an unlimited extent, even though it has itself undergone a considerable change of form. Thus the ultimate follicles of Glands seem to be at first closed cells, which subsequently open at the part nearest to the duct, and establish a connection with it; and having thus changed their condition, they go on developing new generations of secreting-cells in their interior, from their own nuclei or germinal centres, to an unlimited extent. In like manner, the parent-cells of Muscular Fibre, which have coalesced to form the tubular Myolemma, seem to continue to develop new fibrillæ from their nuclei, notwithstanding their change of form.

614. The selecting power, which is possessed by the germs of each kind of tissue, and which enables them to draw from the blood the materials which they severally require for their development, manifests itself also in the mode in which substances, that are abnormally present in the blood, affect the condition and development of the solid tissues. Thus we find that the presence of a certain quantity of Arsenic in the blood, will produce a state of irritation in all the Mucous membranes of the body. The continued introduction of Lead into the circulating system, occasions a modification in the nutrition of the extensor muscles of the fore-arm, producing the form of partial paralysis commonly termed wrist-drop; and the existence of this modification is shown, by the presence of lead in the palsied muscles. Here we have to remark the *symmetrical* nature of the affection, consequent upon the occurrence of the same disorder in the corresponding parts of the two sides of the body; for these muscles appear to have the same kind of tendency to attract lead from the circulating current, in a degree that is equal on the two sides, as they have to draw from the blood the materials of their regular growth, and to develop themselves in an exactly similar manner. In like manner, the cutaneous eruptions, which are occasionally produced by the internal exhibition of iodide of potassium, are found to be almost precisely symmetrical; the presence of the medicine in the blood being the occasion of a disordered nutrition of certain parts of the skin; and the selecting power of particular spots being evinced, by the exact correspondence of the parts affected on the two sides.

615. The same appears to be the case with regard to substances, whose presence in the blood is rather the result of a disordered condition of the digestive and assimilating processes, than of their direct introduction from without. Thus in Lepra and Psoriasis,—chronic diseases of the Skin, which seem to have their origin in a disordered state of the blood, rather than in the solid tissues affected,—we find a remarkable tendency to the repetition of the patches, on the two sides of the body, or on the corresponding parts of the limbs; and this we

must attribute to the peculiar attraction, existing between the solid tissues of those parts, and the morbid matter circulating through them. So in those chronic forms of Gout and Rheumatism, which modify the nutrition of the joints, producing a deposit of "chalk-stones," or permanent distortion and stiffening, we almost invariably find the corresponding joints of the two sides affected. The chief exceptions to the general principle, that the presence of morbid or extraneous matters in the blood affects corresponding parts alike, are found to exist where there is much febrile disturbance, or where local causes produce a peculiar tendency to disorder of a single part. The nearer the character of the morbid process is to that of the ordinary nutritive operations, the more nearly does it approach these, in the *symmetry* with which it develops itself.*

2. *Varying Activity of the Nutritive Processes.*

616. The nutritive operations go on with very great variations in their relative activity, under different circumstances. As a general rule it may be stated that, the greater the demand for the functional activity of the organ or tissue, the more energetic is its nutrition; and *vice versâ*. Now this is readily understood, when it is considered, that the active state of many structures essentially consists in an act of nutrition; thus the energy of the secreting processes is really dependent, as we have seen, upon the growth of the secreting cells, which make up the essential part of the gland; and the energy of the absorbing and assimilating processes is dependent upon the development of the cells, which select and elaborate the nutrient matter. This growth is regulated mainly by the supply of blood; being increased by the afflux of blood towards the part, in consequence of the influence of the nerves upon the vessels, or through any other change in the current of the circulation. Thus the secretions are increased in amount, by emotions of the mind, that act (probably through the sympathetic nerve), in regulating the calibre of the arteries supplying their respective glands; or the interruption of the function of one gland shall occasion an increased nutrition, and consequently an augmented secretion, in its fellow,—as when one of the kidneys is hypertrophied, through a disease in the other, that renders it incapable of performing its office. Still it would appear, that there may be variations in the activity of these organs, resulting from causes inherent in themselves (of the nature of which we know little or nothing); and that here, as elsewhere, active nutritive operations will promote the circulation of blood through the parts, whilst a languid state of the function will retard it.

617. In certain other tissues, however, the functional activity would seem to be dependent rather upon a *waste* or *decay* of structures previously developed; this is the case especially in Nerve and Muscle,

* See Dr. W. Budd's valuable paper on the "Symmetry of Disease," in vol. xxv. of the Medico-Chirurgical Transactions.

which are found to undergo disintegration, in exact proportion to the degree in which they are exercised; whilst the degree in which this waste is repaired, depends upon the supply of nutritive material, the quiescent state of the part, and other circumstances. But even here we find, that functional activity occasions increased nutrition; in the same manner as burning a lamp with a high flame increases the amount of fluid drawn up by the wick. For neither the nerves nor the muscles can act with energy, without a large supply of arterial blood; and this is drawn to them on the principles already mentioned, as increasing the energy of the local circulation (§ 600). The determination of blood to the parts, thus established, favours their increased nutrition; and thus we find that, under favourable circumstances, any set of Muscles, which is habitually exercised, undergoes a great increase of development; whilst, in like manner the Nervous centres, if too great a demand be made upon their activity, are liable to become hypertrophied (especially in young persons), and may thus become subject to disorders, which temporarily or permanently destroy their powers. In these cases, then, the functional activity determines the increased supply of blood, and occasions the augmented growth; and increased nutrition will rarely take place in these tissues, without an especial stimulus of this kind. Thus we find that, when a larger supply of nutritive matter is introduced into the circulation, than is required to repair the waste of these tissues, they do not undergo an increased development in consequence; but an augmented nutrition is produced, either in the adipose tissue, or in the glandular structures by which the superfluous matter is eliminated from the system.

618. Augmented nutrition, or *Hypertrophy*, then, may result, in certain organs, from an excessive supply of their nutrient materials; as in the case of the kidney just mentioned; or as in the enlargement which we not unfrequently meet with in the livers of those who have resided long in warm climates, and who have not sufficiently restricted their supply of non-azotized food to the small amount required for respiration at an elevated temperature, thereby sending an over-supply of that particular class of bodies, to be separated from the blood by the liver. Or, in other cases, the increase of functional activity may be the immediate cause of the increased nutrition; and this we see, not only in the nervous centres and voluntary muscles, which are put in action by the will, but in parts over which the mind has no control. Thus the heart becomes hypertrophied, when an obstruction exists in the pulmonary or systemic circulation, to overcome which, increased energy of contraction is required; and in the same manner, the muscular coats of the urinary and gall-bladders acquire an extraordinary increase of thickness, when long-continued obstruction, by calculi or stricture in the canals issuing from them, impedes the free exit of their contents. Sometimes, however, a local hypertrophy takes place, which cannot be accounted for in either of these modes; as when a single finger is enlarged out of all proportion to

the rest, or the whole of one hand increases to a much greater size than the other, by the existence (as it would seem) in the individual part, of that tendency to unusual development, which, when it affects the whole body uniformly, produces a gigantic stature.

619. Now a precisely reversed series of conditions diminishes the activity of the nutrient processes, and induces a state of *Atrophy.* If there be a deficiency in the general amount of nutriment introduced into the system by absorption, a *general* atrophy results; and the waste being more rapid than the supply, there is a diminution in the volume of all the tissues excepting the nervous, which seems to have its nutrition kept up even to the last, at the expense of all the rest. Such a condition results not merely from the want of food, but also from the want of power to assimilate it; and thus emaciation may take place to an excessive degree, when food of the most nutritive character is copiously applied, and when the appetite for it is vehement; in consequence of disorder in the mesenteric glands, or in some other part of the apparatus particularly concerned in the elaboration of fibrin. A *partial* atrophy may result, in like manner, from a deficiency of the materials required for the formation of an individual tissue or organ; thus the adipose tissue, throughout the body, may be atrophied, in consequence of an absence of those materials in the food, which are capable of being converted into fatty matter. Or a particular organ may be atrophied, by a diminution of the circulating current that should flow to it, either in consequence of obstruction in the trunk, or by the partial diversion of the stream of blood in another direction; thus the liver, which is much more developed in the fœtus, relatively to the rest of the body, than it is in the adult, undergoes a partial atrophy immediately after birth, in consequence of the change in the whole course of the circulation, which takes place as soon as the lungs are expanded.

620. But partial atrophy may also take place from causes inherent in a particular organ. Thus we occasionally meet with limbs, which are "blighted;" never attaining their due size relatively to the remainder of the body; yet not exhibiting any defect of organization. Here there would seem to be, from some unknown cause, a deficient power of growth; analogous to that which, when acting on the body in general, confines it within dwarfish dimensions.—One of the most frequent causes of partial atrophy, however, is want of functional activity in the organ; and this is particularly the case in regard to the Muscular and Nervous systems. Thus, as already remarked (§ 348), any set of Muscles that is long disused, becomes partially atrophied; which is probably due to the feebleness and languor of the circulation, consequent upon the absence of the demand for arterial blood. As soon as the parts are called into use again, their nutrition improves. So, also, in regard to the Nerves; the nutrition of both the fibrous and vesicular structures appears to be entirely dependent upon the activity of their function; and as the former are inert without the latter, we may say that the due nutrition of the nervous system entirely

depends upon the functional activity of the vesicular matter. Of this we have a well-marked illustration in the fact, that, when the Cornea has been rendered so opaque by disease or accident, as to prevent the penetration of any light to the interior of the eye, the retina and the optic nerve lose after a time their characteristic structure; so that scarcely a trace of the peculiar globules of the former, or of the nerve-tubes of the latter, can be found in them.

621. In the healthy condition of the organism, however, the nutrition of every part of the body goes on in a degree sufficient to keep it constantly ready for the performance of its appropriate function; a regular supply of the requisite materials being furnished in the aliment, and being prepared by the assimilating processes; and the products of the waste or decay of the tissues, together with such alimentary materials as may be superfluous, being carried off by the excreting operations. When the nutrition and the waste are equal, the weight of the body remains the same; and this is commonly the case in adult age. But during the earlier periods of life, the powers of growth are greater; the demand for food is very large, in proportion to the bulk of the body; and though the waste is rapid and the excreting processes very active (as evinced by the large amount of urea and of carbonic acid set free), the growth predominates over the decay, and the development of the whole structure proceeds at a gradually decreasing rate, until the full stature and bulk are attained. The energy of the nutritive process is particularly manifested in the rapidity and completeness with which severe injuries, occasioned by disease or accident, are repaired. In advanced life, on the contrary, although the waste is comparatively small, the renewing processes are enfeebled in a still greater degree; and there is a gradual diminution in the stature and bulk of the body, and in its physical powers. All the functions are performed with diminished energy; and the comparative inertness of the nutritive processes is seen in the difficulty with which the effects of severe injuries are repaired, in the length of time requisite for the purpose, and frequently in the imperfection of the result.

622. During the successive periods of life, there are many remarkable changes in the relative nutrition of different organs; which we can attribute to nothing else than to inherent differences in their own powers of development. Thus, during the early stages of fœtal existence, the greatest energy of growth is seen in certain parts, which are to answer but a temporary purpose, and which are afterwards completely atrophied. This is the case, for example, with the Corpora Wolffiana, which seem to answer the purpose of temporary kidneys, and in connection with which the permanent kidneys and the genital organs are developed; and of these bodies, though of large size in the early embryo, and evidently of great importance, no trace whatever is afterwards to be discovered. So in regard to the Supra-Renal capsules, the Thymus and Thyroid glands, and other organs, we find their proportional size the greatest, and their function evidently the most

active, during fœtal existence and in early infancy; after which their bulk diminishes in proportion to the rest of the body, and their functional activity seems almost at an end.

623. Even in the relative development of the organs, which form essential parts of the permanent structure, we find considerable variations at different periods of life. Thus the evolution of the generative system does not usually take place, until the rest of the system is approaching its maturity; but cases sometimes occur, in which this apparatus attains its full development, both in the male and the female, at a very early period of childhood, and seems capable of performing its functions. In the Human species, these organs, when once evolved, remain always in a state of preparation for the performance of their function, unless they are atrophied through complete disuse, or have lost their vigour by age, or through excessive demands upon their activity; but in most of the lower animals, the development of these organs is periodical through the whole of life, taking place at a certain season of the year, and being greatly influenced, it would appear, by the external temperature, and by the supply of food. Thus in the Sparrow, the testes are no larger than mustard-seeds, during the greatest part of the year; but in the spring, they acquire the size of large peas, and it is then only that they possess any procreative power.

624. We are not always to judge of the degree of development of organs, however, by their *size* alone; for the completeness of their structure, and their aptitude for the performance of their functions, must also be taken into the account. Thus in the new-born infant, the organs of digestion and assimilation, though of small size, are so completely formed, as to be able at once to take on the duty of receiving and preparing the nutritive materials, provided these are supplied in a form adapted to their powers; the circulating apparatus is fully adequate to transmit the products of the action of those organs to the body in general, and to bring back the results of its continual decay; and the respiratory organs, together with other parts of the excretory apparatus, are so completely evolved, as to be able to separate the effete matter, and cast it out of the system, with an energy equivalent to that of the organs, by which new matter is introduced and appropriated. On the other hand, the Brain, although of larger comparative *size* at birth, than at any subsequent period of life, is but very imperfectly developed; for its structure is not yet so far completed, as to prepare it for a state of high functional activity. In fact, it would seem as if the use of the organ, as called forth by the new circumstances in which the infant is placed as soon as it comes into the world, is essential to its complete development; and the same may be said of the Muscular system.

625. During the whole period of infancy and childhood, the current of nutrition seems peculiarly directed towards the brain; for though its *size* does not continue to increase in proportion with that of the remainder of the body, its *structure* is evidently being rendered more

perfect, and its functional activity is excited with remarkable facility. Hence it is peculiarly liable to be acted on by various causes, which may produce disease; and the operation of remedies, which specially affect that organ, is far more powerful than at any other period of life. Thus, whilst a child will bear a fourth, or even a third, of the dose of a purgative adequate for an adult, it is strongly affected by an eighth, or even a twelfth, of the dose of a narcotic or a stimulant, that would be required to produce a corresponding effect in middle life. This peculiar impressibility of the nervous system, resulting from the activity of the nutrient processes which are taking place in it, manifests itself also in other ways; thus children are peculiarly liable to have its powers depressed by any sudden shock, such as a blow, or an extensive burn or laceration; whilst, on the other hand, if the depression be not fatal, they recover from its effects much more speedily than an adult would do from a similar condition.

626. During the periods of youth and adolescence, the chief energy of development (except in regard to the generative system, already noticed), appears to be directed towards the Muscular apparatus; which then increases in vigour, in a degree which surpasses its increase of size; and the circulating and respiratory organs, upon whose energetic action there is then a corresponding demand, are peculiarly liable to disturbance of function, inducing disease in themselves or in other parts. The maladies of this period are for the most part of a *sthenic* or *inflammatory* character; resulting, as we shall presently see, from the excessive activity of the assimilating processes, which are disposed to produce more fibrin than the wants of the body require. Or if, on the other hand, there be an imperfect elaboration of the nutrient materials, as happens in the *tubercular* diathesis, its effects are peculiarly liable to manifest themselves at this period, when the demand for nutritive matter is greatly augmented by the activity of the muscular system.

627. In adult age, there should be such a balance of all the functions, arising from the due development and proper use of each organ, as may preserve the body in the state of health and vigour, without any marked change in the relative dimensions of its different parts, through a long series of years. The digestive, assimilating, and excreting organs, as they were the first to come to maturity, are commonly the first to fail in their activity; but this is very generally the result of over-exertion of their powers, the amount of food introduced into the stomach being rarely (among the higher and middle classes of society at least) kept down to the real wants of the system. The muscular apparatus usually experiences the effects of this diminished nutrition sooner than the nervous system; the vigour of the latter being often sustained in a remarkable degree (as shown by the energy of the mental operations) through a protracted life, when it has not been over-tasked at an earlier period. The very slight impairment of the nutrition of the nervous system, during the general emaciation which results from a wasting disease, or during that more gradual

decline of the bodily vigour which is consequent upon advancing age, is a phenomenon which strongly marks it out as the part of the body, to the maintenance of whose integrity everything else is subservient; and this is still more remarkably shown in the phenomena of starvation; in which, notwithstanding the disappearance of the whole of the fat, and the reduction of the weight of the body in general by about 40 per cent., the nervous system appears to lose little or none of its substance (§ 117).

3. *Of Death, or Cessation of Nutrition.*

628. The general cessation of the Nutritive operations, in *Death*, usually depends, as formerly explained (§ 65), upon the cessation of the supply of Nutriment, in consequence of the stagnation of the Circulating current; and this stagnation may result from the *direct* operation of three causes; namely,—failure in the propulsive power of the Heart, or *Syncope*,—obstruction to the flow of blood through the pulmonary capillaries, consequent upon a deficient supply of air, or *Asphyxia*,—and a disordered state of the blood itself (§ 534), which at the same time weakens the power of the heart, and prevents the performance of those changes in the systemic capillaries, which afford a powerful auxiliary to the circulation; a mode of death, for which the term *Necræmia* has been proposed. Each of these conditions may be dependent upon a variety of remote causes, which need not here be particularized. But it is evident that, when either one of them has been established, the nutritive processes must speedily cease, although they may continue for a short time at the expense of the blood in the capillaries of the part. The cooling of the body is another cause of their cessation; and this is one reason why *molecular* death (or the death of the individual organs and tissues) follows so much more closely on *somatic* death (or the cessation of the circulating and respiratory functions), in warm-blooded than in cold-blooded animals. In either case, however, the solid tissues may preserve for a time their independent vitality; and changes may take place in them, which indicate the continuance of their nutritive actions to a certain extent, even when they have been disconnected from the body.

629. Although the death of the several parts composing the fabric is thus due, in the great majority of cases, to the supensions of the supply of the nutritive materials, and to the lowering of the temperature of the body, yet there are undoubtedly cases, in which the loss of vital power is as complete in the solids as in the fluids; the want of ability to avail themselves of nutriment, being as decided in the former, as the deficiency of supply is in the latter. This is seen, for example, when death results from a sudden and violent shock, which destroys the vitality of the whole system alike (§ 604). But it can scarcely be doubted, that we are to attribute the gradual decay and death, which take place in extreme old age without any symptom of local disease, to a similar cause. We have seen that every individual

part of the fabric has its own allotted period of life and activity; each cell passing through a certain series of changes, which are proper to it, and then ceasing to exist; and many organs having only a limited period of activity, and disappearing more or less completely, when this has been accomplished. In both cases, the usual duration of the organ is usually diminished by any previous excess of activity, and increased by moderation in the exercise of its vigour. Thus, the life of the individual cells of the simple cellular plants (on which our observations as to some of the conditions of cell-growth may be best made), is shortened by such external influences as are most favourable to rapidity in their growth and development. And in Man, we constantly notice that the duration of the powers of the Brain and the Generative system is the longest, when these organs have been moderately exercised; and that it is much curtailed by the excessive use of either. The duration of their activity, however, is not increased by partial or entire disuse of the organs; for this induces a state of atrophy, on the principles already mentioned. Now we have every reason to believe, that what is true of individual parts and organs, is true also of the whole structure; and that the existence of the entire bodily fabric may thus come to an end, without any special disease, in consequence of the limit originally set to its powers of self-renovation. It is but rarely, however, that this occurs; the various accidents of life, the neglect of ordinary precautions for the preservation of health, and hereditary tendencies to various kinds of morbid action, being too frequently the means of cutting off the term of Human existence, long before its natural expiration.

4. *Disordered Conditions of the Nutritive Processes.*

630. Having thus passed in review the general conditions, under which the ordinary Nutritive processes take place, it may be well to add a few words in relation to two of their abnormal states; one or other of which is concerned in a very large proportion of the diseases that afflict the human race. In one of these, there is a tendency to the excessive production of Fibrin in the blood; whilst in the other, there is a want of the proper nutritive power in the tissues, which is apparently due to an imperfect elaboration of that important material. The one of these conditions is termed *Inflammation;* whilst the other, which is less active, but more insidious, is known as the *Tubercular Diathesis.*

631. The extraordinary tendency to the production of Fibrin in the blood, which has been already noticed (§ 531) as the most important character of Inflammation, seems to be always conjoined with a depressed vitality of the tissues of some part of the body, which indisposes them to the performance of their regular nutritive operations; and this part may undergo a variety of changes, according to the degree in which it is affected. The depressed condition of its nutritive operations involves, on the principles explained in the preceding

chapter, a languor in the movement of blood through it, together with a distensible state of the capillaries, which causes them to contain a far greater amount of that fluid than under ordinary circumstances. There appears to be, in the vessels of an inflamed part, a peculiar attraction for the white corpuscles of the blood, by which they are drawn together from the circulating current; and there is also a tendency to an increased production of them, which is probably the cause of the increase in the total amount of fibrin. This increase of fibrin in the blood, coupled with a diminished power of appropriating it on the part of the tissues, appears to constitute the essential phenomena of the Inflammatory condition, and to be the cause of the other changes which are characteristic of it.

632. The simplest result of this condition, is the effusion of fibrinous matter, or organizable lymph, into the substance of the part inflamed, or upon the nearest free surface; and thus is produced a condensation of the tissue, or a new growth upon the membrane. But when the depression of vitality is more complete, the tissue at that spot gradually dies and disintegrates; and whilst itself undergoing such changes, it gives origin to similar changes in the effused fibrin, which it converts from a *plastic* or organizable deposit, into an *aplastic* or unorganizable one, namely, *pus*. Thus is produced the Suppurating process; which may either take place in a cavity thus excavated in the substance of a tissue or organ; or on a free surface. In either case, the surrounding tissues, which are less inflamed, and in which the vitality is impaired but not destroyed, become consolidated by a deposition of organizable fibrin, which prevents the infiltration of pus through their substance. If this should not occur, through a want of power to generate well-elaborated fibrin, the suppurating process extends itself rapidly, with the most calamitous results; the properties of pus being such as to produce a tendency to decomposition, both in the blood and in the solid tissues into the substance of which it may be carried.

633. The process termed *Gangrene*, which is the entire loss of vitality in the part, with a complete cessation of the circulation through it, is commonly ranked as one of the results of Inflammation; but it can hardly, in strictness, be so regarded. We have a well-marked illustration of the mode in which this local death takes place, in the case of frost-bites produced by Cold; for this agent at the same time produces contraction of the blood-vessels, and depression of the vital powers of the solid tissues, proceeding to the complete destruction of them; whilst in the parts adjoining those which are actually killed, the inflammatory state is developed; producing an effusion of fibrin, which serves to plug up the mouths of the vessels, and thus to prevent hemorrhage, when the mortified part drops off. Here we see, that the violent action of cold completely destroys the vitality of the part most exposed to it; and this by its direct influence on the properties of the organized structure. No inflammation can take place in the part thus killed, because the vital processes are altogether brought to

an end. But inflammation takes place in the adjoining parts, which are less seriously affected; for the depression of their vital powers occasions the result already adverted to,—namely, the production of an increased amount of Fibrin in the blood, and an infiltration of this substance into their tissues. The same is the case with regard to the operation of other powerful agents; such as those which (like Caustic potass, or Sulphuric Acid) destroy the vitality of the parts to which they are applied, by the chemical decomposition of their tissues. The Inflammatory process is set up, not in the parts which are killed by the application; but in the surrounding tissues, whose vitality has been simply depressed; and thus, when the *slough*, or dead part, is cast off, there is a preparation for the development of new tissue to supply its place, from the superabundant plastic materials of the surrounding parts.

634. If, then, we limit the term Inflammation, as there seems reason to do, to that state, in which there is a tendency to stagnated circulation, with increased production of Fibrin, in the vessels of the part, we see that Gangrene cannot be a result of that process, which is one rather of reparation than of destruction. But Gangrene proceeds, where we can distinctly trace its causes, from the violent operation of the same agents, as those which, in a less degree, produce Inflammation. And where this last process is not set up, at the line of demarkation between the living and the dead parts, Gangrene, like Suppuration, has a tendency to spread; the influence of the decay, which is taking place in one part, having a tendency to propagate itself to the adjoining tissues; and a constantly extending destruction being thus produced.

635. In like manner, certain forms of the *Ulcerating* process may spread, by the action of a peculiar layer of cells, that is found on the surface of the excavation; these cells appear to possess the power of drawing into themselves the materials of the solid tissues on which they lie, and thus of causing their destruction; and this destructive action may take place to an unlimited degree, if no measures be taken to check it. The application of powerful escharotics (such as nitric acid, lunar caustic, or the actual cautery), which is well known to be one of the most efficient methods of treatment in this kind of diseased action, has the effect of destroying these peculiar cells, together with the adjacent tissue which has been partly affected by them; and of exciting an inflammatory action beneath, by which fibrin may be effused, and preparation made for filling up the breach of substance.

636. Now when the reparation of lost parts takes place, it may be effected in either of two modes;—by a process of growth analogous to the natural one;—or by the formation of a new kind of tissue, termed granulation-structure, from the surface of which a formation of pus takes place, until the cavity is completely filled up by it, and closed over by skin, after which the granulation-structure is absorbed, and a contracted cicatrice is left. The former mode of reparation, which takes place in cold-blooded animals, is the slowest, but it is

the most complete; for as the breach of substance is filled up by tissue of a permanent kind, there is no subsequent contraction nor cicatrix; nor is there that waste of plastic matter, nor that constitutional irritation, which is attendant on the suppurating process. It is, consequently, that which the Surgeon should aim to produce; and the means of accomplishing this consists in keeping down the Inflammatory process, and in preventing irritation of the exposed surface.

637. In all cases of injury, there is an increased determination of blood to the neighbouring tissues; and an increased production of Fibrin, to serve as the material for repair. Now if this be moderate in its amount (as it usually is in cold-blooded animals), it will be all consumed in the formation of the new tissue, which is to fill up the vacuity. But if it be excessive, it forms an inflammatory effusion; part of which undergoes a low degree of organization, and becomes granulation-structure; whilst another part is poured forth from the copious but imperfectly-formed vessels of that structure, in an unorganizable state, forming Pus. This change in its character is mainly due to the irritating influence of cold air; which also tends to keep up the excessive production of Fibrin by the Inflammatory process; and the more carefully the raw surface is kept from contact with it, the more healthy will be its action. The low temperature of cold-blooded animals prevents the air from having a like injurious effect upon their wounded surfaces; no exclusion of it seems necessary. In warm-blooded animals the desired end may be attained, either by the application of hot dry air, which causes a scab to form, beneath which the reparative process may take place in complete seclusion from external irritation; or by the formation of an artificial covering, equally closely applied, by means of a waxy or resinous ointment, spread in a liquid state (a measure which has proved peculiarly efficacious in the treatment of burns); or by the application of steam to the wounded surface, which seems to have a remarkably soothing effect upon it; or, where there is a tendency to violent inflammation (as in wounds of the large joints), by keeping the dressings moist by a continual supply of *cool* (but not *cold*) water. All these modes of treatment act in the same manner; tending to exclude irritation, to keep down inflammation, to prevent the over-production of fibrin, and to promote the natural process of slow reparative growth.

638. If the Fibrin of the Blood, however, be not well elaborated, it does not possess its due organizability; and thus, instead of being converted by the Nutritive process into solid tissue, proper to the part in which it is deposited, it is liberated from the vessels in a state, which prevents any but a very imperfect structure from being developed by it. This is the condition of the *Tubercular* substance, which is so often found to replace the proper tissue, especially in the lungs; being slowly deposited there, by a sort of degradation of the regular nutritive operations; and being effused in larger quantity, when the inflammatory process is set up. There is every degree of gradation between the *plastic* or *organizable* deposit of well-elaborated Fibrin,

the *caco-plastic* or *imperfectly-organizable* matter of Tubercle, and the *aplastic* or *non-organizable* matter of Pus. The Microscopic examination of tubercular deposit shows, that they sometimes contain fully developed cells and fibres, analogous to those of fibrinous exudations; but that more frequently, the cells and fibres are imperfectly formed, and are accompanied by a large quantity of a granular substance, which strongly resembles coagulated Albumen; and that in many cases, there is scarcely any trace of organization in the mass. The greatest degree of organization is found in the semi-transparent, miliary, gray, and tough yellow forms of Tubercle; the least in the opaque, crude, or yellow Tubercle.

639. The constitutional state, which predisposes to this perversion of the ordinary nutritive operations, and which is known as the Tubercular Diathesis, is the result of the continued operation of any causes, that tend to depress the vital powers; such as insufficient nutrition, habitual exposure to cold and damp, protracted mental depression, &c.; or it may be derived from the operation of the same or other causes on the ancestors of the individual, being one of those disorders which has a peculiar tendency to become hereditary. The treatment must be directed to the invigoration of the system by good food, active exercise, pure air, warm clothing, and cheerful occupations; and by the due employment of those means, at a sufficiently early period, many valuable lives may be saved, which would otherwise fall a sacrifice to Tubercular disease in the lungs, or other important organs.

640. There is another remarkable class of diseases, resulting from a disordered condition of the nutritive processes;—those, namely, of a *malignant* nature. We not unfrequently meet with abnormal growths of a fatty, cartilaginous, fibrous, or bony structure; which appear to originate in some perverted action of the part itself, and which have little tendency to reappear in the same part, when they have been removed,—still less, to reappear in distant parts. But the various forms of Malignant or Cancerous disease are peculiar in this,—that they are composed of cells, sometimes of a globular form, (see Fig. 30), sometimes elongated or spindle-shaped, having a power of rapid multiplication, and not capable of changing into any other kind of tissue. When a truly cancerous growth has once established itself in any part of the body, it may increase to an unlimited extent, obtaining its nourishment from the blood-vessels in its neighbourhood, and destroying the surrounding parts by its pressure, as well as by drawing off their supply of aliment. When it has developed itself to a considerable degree in one part, it is very liable to make its appearance in others; probably in consequence of the germs of the cells being conveyed in the circulating current to distant portions of the body: and hence the judicious surgeon is disinclined to remove a Cancerous growth of any but the most limited kind; knowing that the disease is almost certain to reappear. There is a strong analogy between such Cancerous growths, and the low forms of Fungoid

Vegetation, which develop themselves in the interior of the higher Plants, and even in Animal bodies; and in both cases, the disease may be propagated by inoculation from one individual to another, the transplantation of a few cell-germs being all that is required.

CHAPTER VIII.

OF RESPIRATION.

1. *Essential Nature and Conditions of the Respiratory Process.*

641. The function of Respiration essentially consists of an interchange of oxygen and carbonic acid between the blood of the Animal and the surrounding medium; carbonic acid being given out by the blood, and oxygen entering in its stead. It has been already noticed (§ 84) that this function is performed likewise by Plants; although, in consequence of their deriving a large part of their food from the atmosphere by a converse process—the absorption of carbon and the liberation of oxygen,—their true respiration is commonly overlooked. It may, therefore, be regarded as common to all Organized beings. Every one is conscious, in his own person, of the imperative demand for the due performance of this operation. If the breath be purposely held for even a few seconds, a feeling of distress is experienced, which increases every moment, and at last prompts irresistibly to the respiratory movement. And if the admission of air to the lungs be in any way prevented, the respiratory movements are at first increased in energy, violent efforts are made to obtain the needed supply; these are succeeded by irregular convulsive actions, and at the same time insensibility comes on; and within a short time all movement ceases, the circulation of the blood is suspended, and a stop is put to all the vital operations of the body. This state, which is termed *Asphyxia*, usually comes on, in a warm-blooded animal, within ten minutes of the time when the respiration is completely suspended; thus affording the most convincing proof of the importance of that function in the Animal economy. In many cold-blooded tribes, a much longer suspension may be borne with impunity; as also by warm-blooded animals, when the general activity of their functions is lowered in the state of *hybernation* (§ 121). We shall now inquire into the sources of the necessity for this interchange of oxygen and carbonic acid; and the mode in which the suspension of it acts upon the system at large.

642. All Organized bodies, as already explained, are liable to continual decay, even whilst they are most actively engaged in performing the actions of Life; and one of the chief products of that decay is

carbonic acid. A large quantity of this gas is set free, during the decomposition of almost every kind of organized matter; the carbon of the substance being united with oxygen supplied by the air. Hence we find, that the formation and liberation of carbonic acid go on with great rapidity after death, both in the Plant and in the Animal; and that they take place also, to a very great extent, in the period that often precedes the death of the body, during which a general decomposition of the tissues is taking place. Thus in Plants, as soon as they become unhealthy, the extrication of carbon in the form of carbonic acid takes place in greater amount than its fixation from the carbonic acid of the atmosphere; and the same change normally takes place during the period that immediately precedes the annual fall of the leaves, their tissue being no longer able to perform its proper functions, and giving rise, by its incipient decay, to a large increase in the quantity of carbonic acid set free. The same thing happens in the Animal body, during the progress of many diseases which are attended with an unusual tendency to decomposition in the solids and fluids,—such as eruptive fevers:—the quantity of carbonic acid set free in Respiration is greatly increased, although the body remains completely at rest; and notwithstanding this, the blood frequently exhibits an unusually dark hue, indicating that it has not been properly freed from the unusual amount of that substance, which it has received from the tissues.

643. Hence, the first object of the Respiratory process, which is common to all forms of Organized being, is to extricate from the body the carbonic acid, which is one of the products of the continual decomposition of its tissues. The softness of many of the tissues of Animals, and the large quantity of fluid contained in their bodies, render them more prone than plants to this kind of decomposition; and, in warm-blooded animals, the higher temperature at which the fabric is usually maintained, adds considerably to the degree of this tendency; so that the *waste* of their tissues, from this cause alone, is as much greater than that of cold-blooded animals as the latter is than that of Plants. But when the temperature of the Reptile is raised by external heat to the level of that of the Mammal, its need for respiration increases, owing to the augmented waste of its tissues. When, on the other hand, the warm-blooded Mammal is reduced, in the state of hybernation, to the level of the cold-blooded Reptile, the waste of its tissues diminishes to such an extent, as to require but a very small exertion of the respiratory process to get rid of the carbonic acid, which is one of its chief products. And in those animals which are capable of retaining their vitality when frozen (§ 136), or when their tissues are completely dried up (§ 159), the decomposition is, for the time, entirely suspended, and consequently there is no carbonic acid to be set free.

644. But another source of Carbonic acid to be set free by the Respiratory process, and one which is peculiar to Animals, consists in the rapid changes which take place in the Muscular and Nervous tissues, during the period of their activity. It has been already shown (§ 361),

that there is strong reason to believe the waste or decomposition of the Muscular tissue to be in exact proportion to the degree in which it is exerted; every development of muscular force being accompanied by a change in the condition of a certain amount of tissue. In order that this change may take place, the presence of Oxygen is essential; and one of the products of the union of oxygen with the elements of muscular fibre is carbonic acid. The same may probably be said of the Nervous tissue (§ 384). Hence it may be stated as a general principle, that the peculiar waste of the Muscular and Nervous substances, which is a condition of their functional activity, and which is altogether distinct from the general slow decay that is common to these tissues with others, is another source of the carbonic acid which is set free from the animal body; and that the amount thus generated will consequently depend upon the degree in which these tissues are exercised. In animals which are chiefly made up of the organs of vegetative life, in whose bodies the nervous and muscular tissues form but a very small part, and in whose tranquil plant-like existence there is but very little demand upon the exercise of these structures, the quantity of carbonic acid thus liberated will be extremely small. On the other hand, in animals whose bodies are chiefly composed of muscle, and whose life is an almost ceaseless round of exertion, the quantity of carbonic acid thus liberated is very considerable.

645. We are enabled to trace the connection between the amount of muscular exertion, and the quantity of carbonic acid set free in the act of respiration, in the class of Insects, better than in any other. They have no fixed temperature to maintain: and they are, consequently, not in the condition of warm-blooded animals, in which the quantity of carbonic acid set free is kept up to a more regular standard by the provision to be presently noticed. On the other hand, they are pre-eminent among all Animals, in regard to the energy of their muscular power in relation to the bulk of their bodies; and the waste of muscular tissue during their state of activity must therefore be very great. Thus, a Humble Bee has been found to produce one-third of a cubic inch of carbonic acid in the course of a single hour, during which its whole body was in a state of constant movement, from the excitement consequent upon its capture; and yet during the whole twenty-four hours of the succeeding day, which it passed in a state of comparative rest, the quantity of carbonic acid generated by it was absolutely less.

646. Besides these sources of Carbonic acid, which are common to all Animals, there is another, which appears to be peculiar to the two highest classes, Birds and Mammals. These are capable of maintaining a constantly elevated temperature, as long as they are supplied with a proper amount of appropriate food; and their power of doing so appears to depend upon the *direct* combination of certain elements of the food, with the oxygen of the air, by a process analogous to combustion; these elements having been introduced into the blood for that purpose, but not having formed a part of any of the solid tissues of the

body, unless they have been deposited in the form of fat. The nature of these substances has been already noticed (§ 430). It is quite clear that they cannot be applied in their original form, to the nutrition of the tissues that originate in proteine-compounds; and it is tolerably certain that in the ordinary condition of the body, they undergo no such conversion as would adapt them to that purpose. The Liver seems to afford a channel, by which some of the fatty matters are drawn off from the blood; but even these seem, in part at least, to be re-absorbed (§ 725), and to be thrown off by the respiratory process.

647. The quantity of carbonic acid that is generated directly from the elements of the food, seems to vary considerably in different animals, and in different states of the same individual. In the Carnivorous tribes, which spend the greater part of their time in a state of activity, it is probable that the quantity which is generated by the waste or metamorphosis of the tissues is sufficient for the maintenance of the required temperature,—and that little or none of the carbonic acid set free in respiration is derived from the direct combustion of the materials of the food. But in Herbivorous animals of comparatively inert habits, the amount of metamorphosis of the tissues is far from being sufficient; and a large part of the food, consisting as it does of substances that cannot be applied to the nutrition of the tissues, is made to enter into direct combination with the oxygen of the air, and thus to compensate for the deficiency. In Man and other animals, which can sustain considerable variations of climate, and can adapt themselves to a great diversity of habits, the quantity of carbonic acid formed by the direct combination of the elements of the food with the oxygen of the air, will differ extremely under different circumstances. It will serve as the *complement* of that which is formed in other ways; so that it will diminish with the increase, and will increase with the diminution, of muscular activity. On the other hand, it will vary in accordance with the external temperature; increasing with its diminution, as more heat must then be generated; and diminishing with its increase.—In all cases, if a sufficient supply of food be not furnished, the store of fat is drawn upon; and if this be exhausted, the animal dies of cold (§ 117).

648. To recapitulate, then; the sources of carbonic acid in the Animal body are threefold.—1. The continual decay of the tissues; which is common to all organized bodies; which is diminished by cold and dryness, and increased by warmth and moisture; which takes place with increased rapidity at the approach of death, whether this affect the body at large, or only an individual part; and which goes on unchecked, when the actions of nutrition have ceased altogether.—2. The metamorphosis, which is peculiar to the Nervous and Muscular tissues; which is the very condition of their activity; and which therefore bears a direct relation to the degree in which they are exerted.—3. The direct conversion of the carbon of the food into carbonic acid; which is peculiar to warm-blooded animals; and which

seems to vary in quantity, in accordance with the amount of heat to be generated.

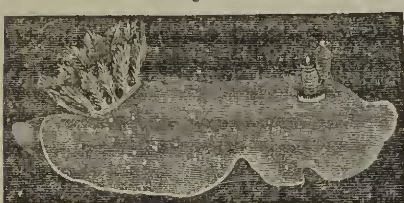
649. Now the function of Respiration has for its object, not merely to extricate the carbonic acid, which is generated in the system; but likewise to introduce the oxygen, which is required to form that carbonic acid;—the proportion of oxygen in the tissues, and in the combustible materials of the blood, not being sufficient for this purpose. Hence it is not enough, that the carbonic acid should be removed; for this may be accomplished by causing an animal to breathe an atmosphere which contains no oxygen. Any cold-blooded animal, such as a Frog or a Snail, may be kept in hydrogen or nitrogen for several hours or even days; and will give out, during that time, an amount of carbonic acid nearly as great as if it had been respiring atmospheric air. But the continued production of carbonic acid must have a limit, occasioned by the want of oxygen, and death will then supervene.—On the other hand, a supply of oxygen may be freely afforded; and yet the presence of even a small amount of carbonic acid in the surrounding atmosphere (in addition to that which is normally present in it, § 81) will impede the extrication of that substance from the blood; and if the excess be considerable, the carbonic acid will not be set free at all; so that the same injurious results follow, as if respiration were altogether prevented from taking place.

650. These two actions are accomplished by the very same act; advantage being taken of the property of "mutual diffusion," which is common to all gaseous substances that do not unite chemically with one another. In virtue of this property, Hydrogen, the lightest of gases, and Carbonic acid, one of the heaviest, when introduced into the same vessel, will be found in a short time to have uniformly mixed, notwithstanding the difference of their specific gravities, which are as 1 to 22. Now this intermixture will take place, when the two gases are separated by a porous septum; each gas passing towards the other, by an action resembling the Endosmose and Exosmose of liquids (§ 491). And it may also take place, when one of the gases is diffused through a liquid; provided that the other gas is likewise capable of being absorbed by the liquid. In this manner, as already mentioned, the surface of venous blood, inclosed in a bladder, may be made to exhibit the arterial hue, by suspending the bladder in an atmosphere of oxygen; for the carbonic acid of the blood, and the surrounding oxygen, will overcome by their mutual attraction the obstacle interposed by the bladder; and the former will be lifted out, so to speak, and will be replaced by the latter. It has been found by experiment, that the free carbonic acid diffused through blood, may be more completely extricated from the liquid, by exposing it to hydrogen, than by placing it under the vacuum of an air-pump; for in the latter case there is nothing to replace it, and the attraction between the gas and the liquid tends to resist the exhausting influence of the vacuum; whilst in the former, the blood receives one gas in exchange for the

other, so that the whole force of the tendency to mutual diffusion is exercised in lifting out the carbonic acid.

651. The immediate purpose of the organs of Respiration, then,—whatever may be the variety in their form,—is this: to expose the blood to the air, in a state of such minute division as to present a very extended surface, a thin membrane only being interposed between them. For this purpose we find a certain organ, or set of organs, specially set apart in all the higher animals; and this is formed by a prolongation of the general surface, either externally or internally, according to the mode in which the respiration is accomplished. Thus in Fishes and aquatic Mollusks, the blood is aërated by exposure, not directly to the atmosphere, but to the air which is dissolved in the water they inhabit; and the respiratory apparatus is formed in them of an extension of the *external* surface, at a particular part, into innumerable delicate fringe-like processes, the *gills* (Fig. 96); every division of which contains a network of blood-vessels (Fig. 100): so that the amount of blood, which is exposed to the surrounding medium at any one time, is collectively very great, although the quantity contained in each gill-filament is very minute. On the other hand, in all the air-breathing Vertebrata, the blood is exposed to the atmosphere, through the medium of an *internal* membranous prolongation, which is continuous with the mucous membrane lining the mouth and nostrils; this forms a pair of sacs, termed *lungs*, communicating with the back of the mouth by means of a tube called the trachea or windpipe, through which air is freely admitted to the cavities thus formed (Fig. 101). The blood is minutely distributed on the walls of these sacs by a close network of capillary vessels (Fig. 102); and not only on the external walls, but also on numerous partitions, by which the cavities are subdivided with more or less minuteness, so as greatly to extend the vascular surface.

Fig. 96.



Doris Johnstoni, showing the tuft of external gills.

652. Such is the essential nature of the Respiratory apparatus; but in order that it may be carried into the vigorous operation, which is required in the higher classes of animals, various supplementary arrangements are made, for the purpose of promoting the due influence of the air upon the blood. In the first place, the capillary vessels of the respiratory surface are connected with arterial trunks, which issue immediately from the heart, and which thus convey a constant stream of blood from that organ; whilst they give origin to venous trunks, which terminate directly in the heart, and which are ready to convey back to it the blood that has undergone aëration. Thus by the energetic action of the heart, and by the force generated in the capillaries of the lungs (§ 598), a constant renewal is effected in the blood,

which is exposed to the air through the medium of these organs. On the other hand, the renewal of the blood would be useless, unless a fresh supply of air were continually being introduced, and that which had been vitiated, by the loss of its oxygen and the admixture of carbonic acid, were removed; and this is effected by a series of muscular movements, which are adapted for the alternate expulsion of the vitiated air from the lungs, and for the introduction of a fresh supply of pure air from the atmosphere. These movements are kept up by a certain part of the nervous system; but they are not dependent upon any exertion of the will, for they continue during profound sleep, and in other states in which even consciousness is altogether suspended.

2. *Different forms of the Respiratory Apparatus in the lower Animals.*

653. Before proceeding to consider, in more detail, the structure and actions of the respiratory apparatus in Man, we may advantageously glance at the mode in which this function is effected in the lower animals.—In the lowest and simplest, which are inhabitants of the water, we do not find any special apparatus for the aëration of the fluids of the body; this being accomplished by the exposure of them to the surrounding medium, through the thin integument; and the interchange of the layer of water (holding air in solution) in contact with the aërating surface, is effected either by the general movement of the body, or by the action of *cilia* (§ 234), which produce the currents necessary for this purpose. Not unfrequently, the internal surfaces—such as the walls of the stomach and of other cavities,—seem as much concerned in this function as the external, or even more so; these cavities being distended with water taken in through the mouth, and this water being frequently renewed, by the ejection of that which has been vitiated, and by the introduction of a fresh supply. This is the case in the Sea Anemone, for example, and in many other Polypes; and there are certain higher forms of the same class, in which there is a great dilatation of the pharynx, which seems peculiarly destined for the aëration of the fluids,—being filled with water, and then suddenly emptied, at tolerably regular intervals.

654. In the various classes of the Molluscous sub-kingdom, we find the respiration provided for, by the adaptation of distinct organs for the purpose. As most of the animals of this group are inhabitants of the water, the respiration is usually carried on by means of gills, rather than by any organs resembling lungs. The latter is found, however, in a few species; such as the Snail, Slug, and other terrestrial air-breathing Mollusks; and usually consists of a simple cavity, situated in the back, communicating directly with the air through an aperture in the skin, and having its walls covered with a minute network of blood-vessels. The form and position of the gills differ extremely in the several classes of Molluscous animals. In the lowest, the respiratory surface is formed, as in the higher Polypes, by a dila-

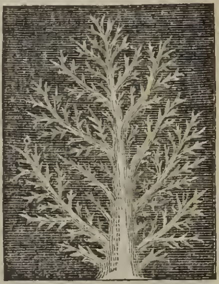
tation of the Pharynx; but sometimes, instead of surrounding a large cavity, it forms a special ribbon-like fold of membrane, passing from one end of it to the other, on which the blood is minutely distributed. In this group of animals, there is a regular system of canals for the conveyance of the blood; but these, in many parts of the system, and especially on the respiratory membrane, do not seem to be furnished with distinct walls, and are rather mere channels excavated in the tissues. And the circulation is liable to a continual change in its direction; the blood being sometimes transmitted to the respiratory surface *before* it proceeds to the body, and sometimes *after* it has traversed the other tissues (§ 557). The water in contact with the respiratory surface is continually renewed by the action of the cilia, with which it is thickly covered.

655. In certain other Mollusks inhabiting bivalve shells, we find that the internal surface of the mantle or skin that lines the valves, is the special organ of respiration; the external water having free access to these, by the separation of the skin along the edges of the valves, so that it enters the cavity in which the viscera are lodged, and bathes their exterior. But in most bivalve Mollusks, the internal surface of the mantle is doubled (as it were) into four ribbon-like folds, which are delicately fringed at their edges, and which have, in fact, the same essential structure as the gills of higher animals (§ 663). To these the blood is transmitted, when it has been rendered venous by traversing the vessels of the body generally; and in these it is exposed, through a surface which is greatly extended by the minute division of the fringes, to the action of water introduced from without, and constantly renewed by ciliary action. In many of these animals, as in the common Oyster, the two lobes of the mantle are so completely separated, that the water can still enter freely between the valves; but in general, they are more or less united, so that the cavity in which the gills lie is partially closed. There is always a provision, however, for the free access of water from without, by means of two apertures, one for its entrance and the other for its ejection; and in certain species which burrow deeply in sand or mud, these apertures are furnished with long tubes, or *siphons*, which convey the water from nearer the entrance of the burrow, and carry it thither again. In these, also, a continued flow of water over the respiratory surface is maintained by the vibration of the cilia, with which they are clothed.

656. The position of the gills, in the Mollusca of higher organization, is extremely variable. Sometimes they are disposed upon the external surface of the body, and form delicate leaf-like or arborescent appendages (Fig. 97); whilst in other cases they are enclosed in a special cavity or gill-chamber, to which water is freely admitted from without; a continual interchange being provided for, either by ciliary action, or by muscular movements specially adapted for the purpose. The blood is conveyed to them, after having become venous in traversing the capillaries of the general system, by means

of large channels and sinuses excavated in the several parts of the body (§ 556); and after being aërated in the gills, it returns to the heart, to be again conveyed to the system. In the Cuttle-fish tribe, there are supplementary hearts at the origin of the branchial arteries,—or vessels that distribute blood to the gills; and these have evidently for their purpose, to render the respiratory circulation more energetic, and thus to increase the aëration of the blood, in the degree required for the vigorous habits of these animals, which present a remarkable contrast to the sluggish inert character of the Mollusca in general.—In these classes, taken as a whole, the respiration is low in its amount. The blood contains no *red* corpuscles, excepting perhaps in the highest class; and the change in its composition, which is effected by the air, is confined, therefore, to the fluid plasma, or liquor sanguinis. And as it is not exposed directly to the air, except in a few species, but to the air contained in the water inhabited by the animals, this change cannot be very energetically performed. But as the life of these animals is chiefly vegetative,—as their movements, except in the highest classes, are few and feeble,—and as they maintain no independent heat,—there is but little need of the interchange, which it is the object of the respiratory process to effect; and these animals can sustain the complete suspension of it for a long time.

Fig. 97.



One of the arborescent processes, forming the gills of Doris Johnstoni separated and enlarged.

657. Among many of the Articulated tribes, the respiration is carried on upon a similar plan. In some of the lowest, such as the Tape-worm of the intestinal canal, there is no special provision for the aëration of the fluids; the soft integument permitting the extrication of carbonic acid, and imbibition of oxygen, in the required degree. This is but very small, however; the life of these animals being almost purely vegetative. In the Marine Worms, which constitute a numerous and interesting group, endowed with considerable locomotive powers, and leading a life of almost constant activity, there is, on the other hand, a special provision for this function; the blood being transmitted, in the course of its circulation, to a series of gill-tufts, which are composed of a delicate membrane prolonged from the external surface of the body, and which sometimes have the form of branching trees, and sometimes of delicate brushes made up of a bundle of distinct filaments. In either case, the filaments are traversed by blood-vessels, and are adapted to bring the blood into close relation with the surrounding water; and the continual interchange of the latter is provided for by the restless movements of the body. The tufts are sometimes arranged along every segment of the body; and their multiplication prevents them from individually attaining any considerable size. In other cases, they are disposed at intervals;

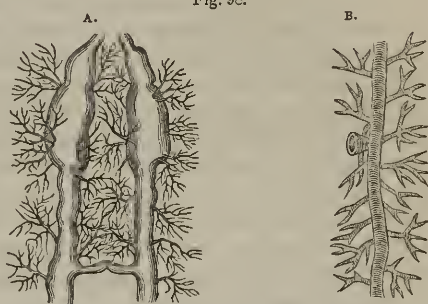
and they are then larger, being less numerous. Their most beautiful development is where they are present on the head only, the rest of the body being enclosed in a shelly or sandy tube, as in the *Serpulæ* and *Terebellæ*. The gill-tufts then frequently present the appearance of a flower, endowed, when alive, with the most brilliant and delicate hues. In many animals of this group, there is a small supplementary heart at the base of every one of the vessels, that distribute the blood to the gills; and this is obviously designed to aid in the respiratory circulation, for which the feeble action of the dorsal vessel would not furnish sufficient power (§ 552).

658. The higher Articulated classes are, for the most part, adapted to atmospheric respiration, on the plan to be presently explained; but there is one class, that of Crustacea, whose respiration is still carried on through the medium of water. In the lowest forms of this group, there is no special respiratory apparatus; the general surface being soft enough to admit of the required aëration of the fluids through its own substance, and the animal functions being performed with so little activity, that a very small amount of interchange is required. In the higher orders, however, whose bodies are encased within a hard envelop, we find external gills, like those of many Mollusks; and these are attached to the most movable parts of the body,—one or more pairs of legs being in some instances kept in constant agitation, for the purpose of producing currents in the surrounding fluid, that may serve for the aëration of the blood. In the Crab-tribe, which constitutes the highest family of this class, the gills are themselves enclosed within a cavity, formed by a sort of doubling of the hard integument of the under side of the body; and a constant stream of water is maintained through this, by means of a peculiar valve, situated in the exit-pipe; the continual movement of the valve causing a regular stream of water to issue from the gill-chamber, and thus occasioning the entrance of a constantly fresh supply. In these, also, we find a dilatation, the walls of which seem to have contractile powers, at the commencement of each artery that distributes the blood to the gills; and this collects the venous blood from the various channels, in which it has meandered through the body. It is by the enclosure of the gills within a cavity, and by the consequent protection of them from the drying influence of the air (which would prevent their function from being duly performed), that Crabs and other allied species are enabled to live for a considerable time out of water; and the Land-Crabs, as they are termed, are adapted to spend the greater part of their lives at a distance from the sea, by means of a special glandular apparatus within the gill-cavity, which secretes a fluid that preserves the surface of the gills in the moist condition, requisite for the aëration of the blood through its membrane. Thus the Land-Crabs are air-breathing animals (except at certain seasons, when they frequent the sea-shores), although they breathe by gills.

659. In Insects and other proper air-breathing Articulata, however, the character of the respiratory apparatus is very different. The transi-

tion from one form to the other is effected through such animals as the Leech and the Earthworm, which seem able to breathe either air or water. These are furnished with a series of small sacs, disposed at regular intervals along each side of the body, and opening by a row of pores, which are termed *spiracles* or *stigmata*. The blood-vessels are distributed upon the walls of these sacs; and either air or water may be introduced into their interior, by the movements of the body, which are adapted to compress their walls, and then to allow them to dilate. In the Centipedes and their allies, these air-sacs send out prolongations; which have not, however, any very ready communication with each other. But in insects, the spiracles, instead of forming the entrances to so many distinct sacs, open into a pair of large tubes, one of which traverses the body on either side, along its whole length. These tubes, termed *tracheæ*, have many communications with each other across the body; and they branch out into innumerable prolongations, the ultimate ramifications of which are distributed to every portion of the system. They occasionally present dilatations of considerable size (Fig. 98, A.); especially in the thoracic region of the body, in those insects, which are endowed with great powers of flight. These dilatations or air-sacs appear destined to serve as reservoirs of air, during the time that the insect is upon the wing, its spiracles being then partially closed; and they may also be useful in diminishing the specific gravity of the body. The air-tubes are prevented from having their cavity obliterated through the pressure of the surrounding parts, by means of an elastic spiral fibre; which winds round them, between their outer and inner membrane, from one extremity to the other (Fig. 98, B.); and which answers the purpose of the cartilaginous rings and plates, in the trachea and bronchi of air-breathing Vertebrata.

Fig. 98.



Respiratory apparatus of insects:—A, air vesicles and part of tracheal system of *Scolia hortorum*. B, portion of one of the great longitudinal tracheæ of *Carabus auratus*, with one of its spiracles.

660. In this manner, the air that is introduced through the spiracles is carried into every part of the body, and is brought into immediate relation with the tissues to be aërated; so that the carbonic acid which they set free is communicated at once to the atmosphere, instead of being taken up by the blood; and the oxygen they require is imbibed in the same manner. And thus we see how the respiration of this interesting class, which is unequaled for its energy when the body is in a state of activity, is provided for without an active circulation of blood, and without the presence of red corpuscles,—which

elsewhere seem to be essential conditions of the interchange of oxygen and carbonic acid between the air and the tissues, wherever this takes place to any great extent.

661. In the Spider tribe, we return to a more concentrated form of the respiratory apparatus; but, notwithstanding that it is limited within much narrower dimensions externally, it exposes a very large amount of surface on its interior. It consists of a series of sacs, much less numerous than in the lower Articulata, and not communicating with each other. Their lining membrane, however, is doubled into a series of folds, which lie in proximity with each other, like the leaves of a book, and which thus present a very extensive surface within a very small space. Over this surface, the blood is distributed in a minute capillary network; and thus it comes into immediate relation with the air, which is received into the cavity through its aperture or spiracle. The alternate admission and expulsion of air seem to be provided for, as in Insects, by movements of the body, which first empty the cavities or air-tubes by compression, and then allow them to be re-filled by their own elasticity, the pressure being relaxed. The respiratory cavities in the Spider-tribe have received the name of *pulmonary branchiæ;* from their analogy, on the one hand, with the lungs of higher animals; and, on the other, with the branchial or gill-cavity of the higher Crustacea, the gills in which are formed by prolongations of the lining membrane, like the leaf-like folds in the air-cavities of the Spider-tribe.

662. The accompanying diagram will give an idea of the relations of these different forms of the respiratory apparatus, amongst themselves, and to that of Vertebrata. Let the line A B represent the general

Fig. 99.

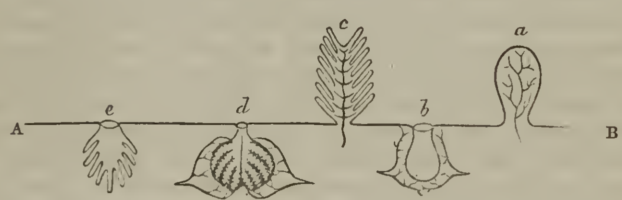


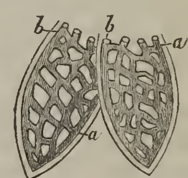
Diagram illustrating different forms of the Respiratory apparatus:—*a*, simple leaf-like gill; *b*, simple respiratory sac; *c*, divided gill; *d*, divided sac; *e*, pulmonary branchia of Spider.

surface of the animal; the continuations of that line on its upper side being its *external* prolongations; and those *below*, its *internal* prolongations or reflexions. Now at *a* is seen the character of the simple foliaceous or leaf-like gill, such as is found in the lower aquatic animals; presenting merely a flat expanded surface in contact with the water, over which the blood may be distributed. At *b* is shown a correspondingly simple inversion; such as that which forms the respiratory sac of the leech, having the blood-vessels distributed upon its walls. A higher form of the gill, such as is found in fishes and

in the higher aquatic Invertebrata, is seen at *c*; the surface being greatly extended, by subdivision into minute filaments. A more complex form of the pulmonary apparatus, such as is found in the higher Vertebrata, is shown at *d*; the blood being distributed, not merely to its outer walls, but to the minute partitions which subdivide its cavity into cells. And at *e* is represented the respiratory organ of the Spider-tribe; which bears an obvious resemblance to the lung of the Vertebrated animal, shown at *d*; whilst it is evidently as nearly allied to the gill shown at *c*, provided this be imagined to be sunk within a cavity formed by a depression of the external surface, instead of projecting beyond it.—Thus we see how very close is the real resemblance between all the forms of the respiratory apparatus; however unlike each other they may at first sight appear to be.

663. The gills of Fishes correspond with those of the higher Mollusca in all essential particulars; but they are more largely developed in proportion to the size of the body; and they are placed in a situation that enables them to receive a more regular and constantly-changed supply, both of blood and water. The gills are suspended to bony or cartilaginous arches, of which three, four, or more, are fixed on either side of the neck; and the fringes hang loosely within a cavity, which communicates on the one hand with the mouth, and on the other with the exterior of the body. The mechanism of respiration is very complex in these animals; and is evidently adapted to produce the most effectual aëration possible. The mouth is first distended with water; and its muscles are then thrown into contraction, in such a manner as to expel the water, through the aperture on either side of the pharynx, into the gill-cavity. At the same time, the bony arches are lifted and separated from each other, by the action of muscles especially adapted to this purpose; so that the gill-fringes may hang freely, and may present no obstacle to the flow of the water between them. When they have been thus bathed with the aërating liquid, and their blood has undergone the necessary change, the water is expelled through the outward aperture on each side of the back of the neck; which is furnished with a large flap or valvular cover termed the operculum. In some of the cartilaginous Fishes, each branchial arch is inclosed in a separate cavity; which communicates on the inner side with the pharynx by an orifice peculiar to itself, and by another orifice with the external surface. Thus there is a series of external openings, instead of a single one, on each side of the neck; and these sometimes amount to six or seven, as in the Lamprey, reminding us of the spiracles of Articulated animals; whilst there is a corresponding series of internal

Fig. 100.



Capillary network of a pair of leaflets of the gills of the Eel:—*a*, *a*, branches of the branchial artery conveying venous blood; *b*, *b*, branches of branchial vein, returning aërated blood. The disappearance of the dark shading in the network, as it traverses the gill, is designed to indicate the change in the character of the blood, as it passes from one side to the other.

openings into the pharynx on either side, or into a tube that communicates with it.

664. It is well known, that most Fishes speedily die when removed from the water; and it can be easily shown, that the deficient aëration of the blood is the immediate cause of their death. But as it might have been expected, that the atmosphere would exert a much more energetic influence upon the blood contained in the gills, than that which is exercised by the air contained in the water, the question naturally arises, how this deficient aëration comes to pass. It is chiefly due to the two following causes; the drying up of the membrane of the gills themselves, where it is exposed to the air, so that the aëration of the blood is impeded;—and the flapping together of the filaments of the gills, which no longer hang loosely and apart, but adhere in such a manner as to prevent the exposure of the greater portion of their surface to the air. Those fishes live longest out of water, in which the external gill-openings are very small, so that the gill-cavity may be kept full of fluid; and there are certain species which are provided like the Land-crab, with a particular apparatus for keeping the gills moist, and which perform long migrations over land in search of food, even (it is said) ascending trees. These are exceptions to the general rule.

665. The respiration of Fishes is much more energetic than that of any of the lower aquatic animals; and this is partly due to the great extension of the surface of the gills, partly to the provision just explained for maintaining a constant flow of fresh water over their surface, and partly to the position of the heart at the base of the main trunk that conveys the blood to the gills (§ 558), by which the regular propulsion of that fluid through these organs is secured. Their blood, too, is furnished with red corpuscles; which give important aid in conveying oxygen from the gills to the remote tissues of the body, and in returning the carbonic acid to be excreted. The proportion of these varies considerably, in the different species of the class, being very small in those that approach most nearly to the Invertebrata; and there is even an entire absence of them in one remarkable fish, the Amphioxus or Lancelot; whilst they are present in large numbers in the blood of certain Fishes, which have great muscular activity, and can maintain a high independent temperature.

666. It would seem, however, that not even this high amount of respiration is always sufficient for Fishes, which live in small collections of water, where their temperature is liable to be greatly augmented by the heat of summer; under which condition, there is an increased proneness to disintegration in their tissues, and a corresponding necessity for the extrication of carbonic acid and for the absorption of oxygen. Many fresh-water fishes under such circumstances, may be seen to come to the surface and to *swallow* air; and it would seem as if the interior of the intestinal canal then served the purpose of a respiratory surface, the air being expelled from the anus,

deprived of a large part of its oxygen, and highly charged with carbonic acid.

667. In addition to their apparatus for aquatic respiration, many Fishes are provided, in their *air-bladder*, with the rudiments of the air-breathing apparatus of higher animals; although it is only in certain species, which approach Reptiles in their general organization, that this really affords any aid in the aëration of the blood. The air-bladder in its simplest condition is entirely closed; and it is then obviously incapable of taking any share in the respiratory function, although it seems to be an organ of some importance to the animal, in regulating its specific gravity, and altering its position in the water. In other cases, it communicates with the intestinal tube by a short wide canal, termed the *ductus pneumaticus;* and this may serve to admit air, which is taken into the alimentary tube by the process of swallowing just mentioned. In the *Sauroid* Fishes, just adverted to, the air-bladder forms a *double* sac, which is evidently the representative of the double-lung of the air-breathing Vertebrata; and it communicates with the back of the mouth by a regular trachea or windpipe, which has a muscular valve at its commencement, serving to open or close its orifice. Some of these fishes are able to live for a considerable time out of water, their respiration being maintained by these rudimentary lungs; and they can also make a hissing sound, by the expulsion of the air-sacs through the narrow glottis, or entrance to the trachea.

668. The condition of the Respiratory apparatus, and the mode in which the function is performed, in the class of Reptiles, are peculiarly interesting; as it is in this class, that we first meet with the complete adaptation of the Vertebrated structure to the aëration of the blood by the direct influence of the atmosphere. Their general habits of life require but a very feeble amount of aëration, especially at moderate temperatures; their muscular and nervous systems being usually exercised in a very low degree; their movements being sluggish, and their perceptions obtuse. In fact, they may be considered, on the whole, as the most vegetative of all Vertebrated animals. In accordance with this character, the lungs are so constructed, as not to expose any very large amount of blood to the air at any one time; and, as we have already seen (§ 563), only a portion of the stream of the circulation is diverted to the lungs; the main current being sent to the system with only that amount of aëration, which it has derived from the admixture of the portion of blood that has been aërated in the lungs, with the venous current that has last been returned from the system.

669. The lungs of Reptiles are, for the most part, capacious sacs, occupying a considerable part of the cavity of the trunk; but they are very slightly subdivided, so that the amount of surface they can expose is really small. Where any subdivision exists, it is usually at the upper extremity of the lung, near the point of entrance of the bronchial tube; and where there is no actual subdivision of the cavity,

we usually find that its surface is extended in this situation, by the formation of a number of little depressions or pouches in its walls, upon which the blood-vessels are minutely distributed. The greatest amount of subdivision is seen in the lungs of the Turtle tribe; but even in these, the partitions scarcely form a complete division at any part of the lungs; and the ultimate air-cells are of very large size. The air-sacs of Reptiles are not filled, like those of Mammalia, by an act of inspiration, but by a process of swallowing, which is comparatively tedious; and, from the small amount of aërating surface, in proportion to the amount of air thus received into the cavity, one inflation of the air-sacs lasts for a considerable time. When the replacement of oxygen by carbonic acid has proceeded to an extent that renders the air no longer fit to remain in the lungs, these cavities are emptied by pressure exercised upon them by the muscles of the trunk; and the slow exit of the air through the narrow glottis is accompanied by a prolonged hissing sound, which is the only sort of voice that is possessed by the greater part of the Reptile class. The lungs are again filled by the swallowing-process; and all goes on as before.

Fig. 101.

Section of the Lung of the Turtle.

670. Now in the Frog tribe, which forms the lowest order of Reptiles (and which is sometimes ranked as a distinct class, under the title of Amphibia), the respiration, during the early or *Tadpole* state, is aquatic; being carried on by means of gills, and conducted exactly upon the plan of that of Fishes. The lungs are not developed, until a period long subsequent to the animal's emersion from the egg; and as soon as they are ready to come into play, an alteration begins to take place in the circulating system, by which the current of blood is diverted towards them, and away from the gills (§ 562). This change takes place to its full extent in the Frog, Toad, Newt, and their allies; which henceforth have a respiration and a circulation exactly analogous to that of Reptiles in general; but it is checked in the Proteus, Siren, and other species, which form the *perennibranchiate* group,—so called from the persistent character of their gills, which still remain in action, the lungs never being sufficiently developed to maintain the respiration by themselves. The curious influence which Light possesses on this metamorphosis, has been already referred to (§ 95).

671. This order *Batrachia* is further distinguished from other Reptiles, even when the metamorphosis is complete, by the softness and nakedness of the skin; which is destitute of the scales and horny plates, that cover it in the Lizards, Serpents, and Tortoises. The

skin of the Frog tribe is a very important organ of respiration; being richly supplied with blood-vessels; and exposing their contents to the influence of the air, under circumstances nearly as favourable as those afforded by the imperfectly-developed lungs of these animals. Thus a Frog, from which the lungs have been removed, will live a considerable time at a moderate temperature, if its skin be freely exposed to a moist air; for in consequence of the peculiar mode in which the circulation is carried on in these animals (§ 562), the interruption to the flow of blood through the lungs does not (as in the higher classes) produce a stagnation of the general current through the body; and the blood receives, in its course through the skin, a sufficient amount of aëration for the support of life. Indeed at a low temperature, the influence of water on the skin is sufficient (by means of the air included in the liquid) to remove the small amount of carbonic acid then ready for excretion, and to supply the requisite amount of oxygen; and Frogs may thus live beneath the water for any length of time, without coming to the surface to breathe. But with the rise of the temperature of their bodies, their blood requires a higher degree of aëration; and they then come to the surface to take in air by the mouth, which aërates the blood through the lungs. It appears that, during the heat of summer, the pulmonary respiration, and the influence of the water on the skin, are not sufficient; as it is found that Frogs die, if they are confined to the water under such circumstances, —their natural habit being to quit the water at such times, so that the air may exert its full influence on their skin as well as on their lungs. They do not, however, quit the neighbourhood of water, and soon die if exposed to a dry atmosphere; for if the skin become dry, its aërating function can be no longer performed. The same result happens, if the passage of gases through the skin be impeded by smearing it over with any unctuous substance. We shall presently find reason to believe, that this cutaneous respiration is a very important part of the function, even in Man and the Mammalia.

672. The class of Birds presents a most striking contrast to that of Reptiles, in regard to the energy of the respiratory function, and the extent of the apparatus destined to its performance. The lungs in these animals undergo a minute subdivision; so that the extent of surface, over which they expose the blood to the air, is greatly increased. But this subdivision is not carried to the same degree of minuteness as it is in Mammalia; and the required extent of surface would not be afforded by the lungs alone. In addition to these organs, we find large air-sacs, communicating with them, disposed in different parts of the body,—such as the abdominal cavity, the interspaces among the muscles, the spaces between the muscles and the skin, &c. These very greatly increase the respiratory surface; their lining membrane being extremely vascular, and adapted to expose the blood to the influence of the air. In most Birds, the bones themselves are hollow; and the lining membrane of their cavities serves as an additional aërating surface, the air being introduced into the interior of

the bones, by canals that communicate directly with the lungs. So free is this communication, that the respiration has been known to be maintained through the fractured humerus of an Albatross, when an attempt was made to destroy the bird by compressing its trachea. Thus the respiratory surface is extended into the remoter parts of the system, very much as in Insects; and the hollowness of the bones, together with the presence of numerous air-sacs in different parts of the body, contribute to diminish its specific gravity. The large quantity of air thus included in different portions of the frame, also serves, like that contained in the air-sacs of Insects, as a reservoir for the supply of the principal aërating organs during active flight, when the respiratory movements are less free.

673. The mechanism of Respiration in Birds is very different from that which produces the respiratory movements in Mammalia. The cavities of the chest and thorax are not yet separated by a diaphragm; except in a very small number of species, that approach most nearly to the next class. But, on the other hand, the whole cavity of the trunk is more completely enclosed in a bony casing; the ribs being connected with the sternum by osseous prolongations from the latter, instead of by cartilages; and the sternum itself being so largely developed, as to cover almost the entire front of the body. Now the natural condition of this bony framework is such, that when no pressure is made upon it, the cavity it encloses is in a state of distension; and the state of emptiness can only be produced by a forcible compression of the framework, through an exertion of muscular power. The lungs, instead of being freely suspended in the cavity of the chest, as in Mammalia, are attached to the ribs; and their own tissue is endowed with a degree of elasticity, which causes them to dilate when they are permitted to do so. In the state of distension, therefore, which is natural to the cavity of the trunk, the lungs are expanded, and fill themselves with air, which they draw in through the trachea; and this condition they retain, until, by the action of the external muscles upon the bony framework, the cavity of the trunk is diminished, and the air is expelled from the lungs and air-sacs, which are again filled as soon as the pressure is taken off.—As the air-sacs chiefly communicate with the part of the lungs that is most distant from the trachea, the air has to traverse the whole extent of these last organs, both when it is being drawn into the air-sacs, and when it is being expelled from them; so that it is made to serve for the aëration of the blood in the most effectual manner.

674. Thus, although the respiratory apparatus of Birds does not possess the highly-concentrated development, which we shall find it to present in Mammals, it serves, by the extension of the aërating surface through the body, to bring the air and the blood into most intimate relation; and the energy of the function is further provided for, by the mode in which the pulmonary circulation is carried on (a distinct heart, as it were, being provided for it, § 564), as well as by the arrangement of the blood-vessels, which transmit to the respira-

tory organs the whole of the blood, that has been returned in a carbonated state by the great veins of the system. The very large proportion of red corpuscles contained in the blood, gives additional effect to these provisions. The very high amount of respiration which is natural to Birds, and which cannot be suspended even for a short time without fatal consequences, has a direct relation (as already explained) with their extraordinary muscular activity; and with the high bodily temperature, which they are fitted to maintain, and which cannot be lowered in any great degree without the suspension of their other functions. Birds are peculiarly susceptible of impurities in the atmosphere; and it has been shown by experiment, that if a Bird, a Mammal, and a Reptile, be placed together in a limited quantity of air, which gradually becomes vitiated by their respiration, the Bird will die first, the Mammal next, and the Reptile last. Or if the Bird be placed alone in a limited quantity of air, and be left until the atmosphere is so vitiated as to be no longer capable of supporting its life, a Mammal will still live for a time in that atmosphere; and when it is no longer fit to sustain the life of the Mammal, the Reptile may still breathe it without injury for a considerable period. There is strong reason to believe, indeed, that in former epochs of the Earth's history, when the Reptile class was predominant, supplying the place of Mammals on land, and of Birds in the air, the atmosphere was so highly charged with carbonic acid, as not to be capable of sustaining the life of the higher air-breathing Vertebrata.

3. *Mechanism of Respiration in Mammalia and in Man.*

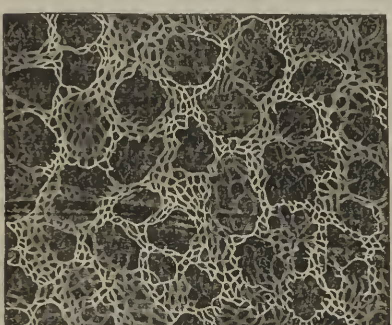
675. It is in the class of Mammalia, that we find the Respiratory apparatus presenting its highest degree of concentration; and the arrangements for its action the most complete. The lungs are divided into cavities of extreme minuteness; so that the extent of surface which they expose is enormously increased. These cavities, or air-cells are all connected with the trachea, by means of the bronchial tubes and their minute subdivisions; but on account of the minuteness of these passages, a considerable force would be required to inflate the air-cells with air, if their distension were to be accomplished by the propulsion of air through the trachea, as we have seen to be the normal mode of inspiration in Reptiles. Moreover, if the air were introduced in this manner, the air-cells would be the *last* portions of the pulmonary structure that would be distended by it; as well as the first to be emptied, when the air is forced out again by external pressure. The mechanism of Respiration in Mammalia, however, is so arranged, that the air is most effectually *drawn into* the lungs; instead of being *forced into* them; and the distension of the air-cells is far more complete than it could be rendered in the latter method, besides being accomplished in a much shorter time.

676. The general principle of the operation is this. The lungs are suspended in a cavity that is completely closed; being bounded above

and around by the bony framework of the thorax, the interspaces of which are filled up by the muscles and membranes; and being entirely cut off from the abdomen below, by the diaphragm. Under ordinary circumstances, the lungs completely fill the cavity; their external surface, covered by the pleura, being everywhere in contact with the pleural lining of the thorax. But the capacity of the thoracic cavity is susceptible of being greatly altered by the movements of the ribs, and by the actions of the diaphragm and abdominal muscles; as will presently be explained in more detail. When it is diminished, the lungs are compressed, and a portion of the air contained in them is expelled through the trachea. On the other hand, when it is increased the elasticity of the air within the lungs causes them immediately to dilate, so as to fill the vacuum that would otherwise exist in the thoracic cavity; and a rush of air takes place down the air-tubes, and into the remotest air-cells, to equalize the density of the air they include (which has been rarefied by the dilatation of the containing cavities) with that of the surrounding atmosphere.

677. The diameter of the ultimate air-cells of the Human lung varies from about the 1-200th to the 1-70th of an inch. Their shape is irregular; and their walls are, for the most part, flattened against each other. Each of the ultimate ramifications of the bronchial tubes communicates with a cluster of these air-cells grouped around it; those which are in immediate proximity with the tube open into it by well-defined circular apertures; and the others communicate with it by opening into these and into each other. Each air-cell is lined by an extension of the mucous membrane from the bronchial tubes, and this is covered by a delicate pavement-epithelium. Between the adjacent air-cells, is a network of fibrous tissue, that forms the connecting medium by which they are held together; this tissue appears to be of the elastic kind. The pulmonary arteries subdivide into branches, whose ultimate ramifications form an extremely minute capillary plexus; and this is disposed between the walls of the adjacent air-cells, so that each portion of this plexus comes into relation with the air (through the lining membrane of the contiguous air-cells) on *both* sides,—an arrangement which is obviously the most favourable that can be to the aëration of the contained blood. It has been calculated by M. Rochoux, that the number of air-cells grouped around each terminal bronchus is little less than 18,000; and that the total number in the lungs amounts

Fig. 102.



Arrangement of the Capillaries of the air-cells of the Human Lung.

to *six hundred millions.* If this estimate be even a remote approximation to the truth, it is evident that the amount of surface exposed by the walls of these minute cavities, must be very many times greater than that of the exterior of the body.

678. The larger bronchial tubes are more or less cartilaginous; but the smaller branches do not possess any such deposit in their walls, though still retaining their circular form. We find in the latter a fibrous structure, which seems to possess the properties of non-striated muscle; and by this, the diameter of these tubes appears to be governed. The contractility of the walls of the smaller bronchi may be excited by chemical, electrical, or mechanical stimuli applied to themselves; though it is not readily caused to manifest itself by stimulating the nerves. By the continued influence of galvanism, bronchial tubes of a line in diameter have been made to contract, until their cavity was nearly obliterated. What purpose this contractility may serve, during the ordinary actions of the lungs, it is not easy to say; but it manifests itself strongly in certain diseased conditions, especially in Spasmodic Asthma, which appears essentially to consist in a contracted state of the smaller bronchial passages, occasioning an interruption to the passage of air through them. It is interesting to observe, that the contractility of the muscular walls of these tubes has been experimentally found to be greatly diminished by the application of vegetable narcotics, especially stramonium and belladonna,—substances which are well known to have a powerful remedial influence in spasmodic Asthma.

679. The Lungs themselves appear to be, almost entirely, passive instruments of the Respiratory function. Their contraction when over-distended, and their dilatation after extreme pressure, may be partly due to the elasticity of their structure; which seems to produce, when acting by itself, a moderately distended state of the air-cavities. This, too, is the condition that seems most natural to the cavity of the chest; the fullest dilatation, or the most complete contraction, of which it is capable, being only accomplished by a forcible effort.

680. The dilatation of the cavity of the chest, which constitutes Inspiration, is accomplished by two sets of movements;—the elevation of the ribs,—and the depression of the diaphragm. From the peculiar mode in which the ribs are articulated with the spinal column at one extremity, and from the angle which they make with the cartilages that connect them to the sternum at the other, the act of elevation tends to bring the ribs and the cartilages more into a straight line, and to carry the former to a greater distance from the median plane of the body, whilst the sternum is also thrown forwards. Consequently the elevation of the ribs increases the capacity of the thorax, upwards, forwards, and laterally. The movement is chiefly accomplished by the Scaleni muscles, which draw up the first rib; and by the Intercostals, which draw the other ribs into nearer proximity with each other, so that the total amount of movement in each rib increases as we pass from above downwards,—every one being drawn up by its

connection with the one above it, and being drawn nearer to it by the action of its own intercostals. The elevation of the ribs is further assisted by the serratus magnus, and by other muscles connected with the spine and the scapula; and when the respiratory movement is very forcibly performed, the scapula is itself drawn upwards, by the muscles that descend to it from the neck, thus producing an increased elevation of the ribs, and an unusual enlargement of the upper part of the thoracic cavity.—When the respiratory action is to be performed, the descent of the ribs is occasioned by the muscles of the spine and abdomen, which proceed upwards from the lower part of the trunk; and this action is aided by the elasticity of the costal cartilages.

681. In the ordinary act of inspiration, however, the diaphragm performs the most important part. The contraction of this muscle changes its upper surface, from the high arch that it forms when relaxed and pushed upwards by the viscera below, to a much more level state; though it never approaches very closely to a plane; being somewhat convex, even when the fullest inspiration has been taken. When thus drawn down, it presses upon the abdominal viscera, and causes them to project forwards, which they are allowed to do, by the relaxation of the abdominal muscles. In tranquil breathing, this action is alone nearly sufficient to produce the requisite enlargement of the thoracic cavity; the position of the ribs being very little altered. In the expiratory movement, the diaphragm is altogether passive; for, being in a state of relaxation, it is forced upwards by the abdominal viscera, which are pressed inwards by the contraction of the abdominal muscles. These last, therefore, are the main instruments of the expiratory movement; diminishing the cavity of the chest by elevating its floor, at the same time that they draw its bony framework into a narrower compass.

682. In this manner, by the regularly alternating dilatation and contraction of the thoracic cavity, the air within the lungs is alternately increased and diminished in amount; and thus a regular exchange is secured. This exchange, however, can only affect at any one time a certain proportion of the air in the lungs; thus it is probable, that the quantity remaining in these organs after ordinary expiration is above 100 cubic inches, whilst the amount usually expired is not above 20 cubic inches. Indeed if it were not for the tendency of gases to mutual diffusion, the air in the remote air-cells might never be renewed.—If any aperture exist, by which air could obtain direct access to the pleural cavity, the lungs would not be dilated by its enlargement; for the vacuum would be supplied much more readily, by the direct ingress of the air (provided the aperture be large enough), than by the distension of the lung. Thus a large penetrating wound of the thoracic cavity may completely throw out of use the lung of that side; and the same result will follow, when an aperture forms by ulceration in the substance of the lung itself, establishing a free communication between the pleural cavity and one of the

bronchial tubes; so that, of the air which rushes in by the trachea, to compensate for the enlargement of the thoracic cavity, a great part goes at once into that cavity, without contributing to the distension of the lungs, and therefore without serving for the aëration of the blood.

683. The number of the respiratory movements (that is, of the acts of inspiration and expiration taken together) may be probably estimated at from 14 to 18 per minute, in a state of health and of repose of body and mind. Of these, the greater part are moderate in amount, involving little movement except in the diaphragm; but a greater exertion, attended with a decided elevation of the ribs, is usually made at every fifth recurrence. The frequency of the respiratory movements, however, is liable to be greatly increased by various causes, such as violent muscular exertion, mental emotion, or quickened circulation; whilst it may be diminished by torpidity of the nervous centres, on which the movement depends,—as we see in apoplexy, narcotic poisoning, &c. An acceleration seems very constantly to take place in diseases, which unfit a part of the lung for the performance of its function; and the rate bears a proportion to the amount thus thrown out of use. Thus, the usual proportion between the respiratory movements and the pulse being as 1 to $4\frac{1}{2}$ or 5, it may become in Pneumonia as 1 to 3, or even in severe cases as 1 to 2; the increase in the number of respiratory movements being much greater in proportion, than the augmentation of the rate of the pulse. But it must be remembered by the practitioner, that a simply hysterical state may produce, in young females, an extraordinary acceleration of the respiration; the number of movements being sometimes no less than 100 per minute. There will be a great increase, also, in the number of inspirations, when the regular movements are prevented from being fully performed, by any cause that affects their mechanism, even whilst the lungs themselves are quite sound. Thus in inflammation of the pleura or pericardium, or in rheumatic affections of the intercostal muscles, the full action of the ribs is prevented by the pain which the movements produce; and the same is the case in regard to the diaphragm, when the peritoneum or the abdominal viscera are affected with inflammation. Under such circumstances, there is an involuntary tendency to make up for the deficiency in the *amount* of the respiratory movements, by an increase in their *number*.

684. The combined actions of the respiratory muscles, which have been now explained, belong to the group termed *reflex;* being the result of the operation of a certain part of the nervous centres, which does not involve the will, or even sensation, and which may continue when all the other parts of the nervous centres have been removed. In the Invertebrated Animals, we commonly find a distinct ganglionic centre set apart for the performance of the respiratory movements; and the division of the nervous centres in Vertebrated animals, which is the seat of the same function, may be clearly marked out, although it is not so isolated from the rest. It is, in fact, that segment of the medulla oblongata and upper part of the spinal cord, which is con-

nected with the 5th, 7th, and 8th pairs of cephalic nerves, and with the phrenic. The entire brain may be removed from above (by successive slicing), and the whole spinal cord may be destroyed below; and yet the respiratory movements of the diaphragm will still continue,—those of the intercostal and other muscles being of course suspended, by the destruction of a portion of the cord, from which their nerves arise. But if the spinal cord be divided, between the point at which it receives the 5th and 8th pairs of nerves, and that at which it gives origin to the phrenic, the movements of the diaphragm immediately cease; and this is the reason why death is so instantaneous, in cases of laxation or fracture of the higher cervical vertebræ, causing pressure upon the spinal cord just below its exit from the cranium; whilst if the injury take place below the origin of the phrenic nerve, life may be prolonged for some time.

685. The Respiratory movements, like other reflex actions (§ 394), depend upon a *stimulus* of some kind, originating at the extremities of the nerves, propagated towards the centre by the afferent trunks, and giving rise to a motor impulse, which is transmitted along the efferent or motor nerves to the muscles, and which occasions their contraction. Now the importance of the respiratory function to the maintenance of life, which has already been sufficiently pointed out, necessitates an ample provision for its due performance; and thus we find that the stimulus for the excitement of the movements may be transmitted through several channels. Its chief source, no doubt, is in the lungs; and arises from the presence of venous blood in the capillaries and of carbonic acid in the air-cells. Under ordinary circumstances, —that is, when the blood is being duly aërated, and the air being properly renewed,—the impression thus made upon the nerves of the lungs, is so faint, that we cannot perceive it, even when we specially direct our attention to it. But if we suspend the movements for a moment or two, we immediately experience a sensible uneasiness. The Par Vagum is obviously the channel, through which this impression is conveyed to the nervous centres; and it is found that, if the trunk of this nerve be divided on both sides, the respiratory movements are greatly diminished in frequency. Hence it is undoubtedly one of the principal *excitors* of the respiratory movements.

686. But the sensory nerves of the general surface, and more particularly the sensory portion of the Fifth pair, which supplies the face, are most important auxiliaries, as *excitor* nerves; the inspiratory movement being peculiarly and forcibly excited by impressions made upon them, especially by the contact of cold air or water with the face. The power of the impression made by the air upon the general surface, and particularly upon the face, in exciting the inspiratory movement, is well seen in the case of the first inspiration of the newborn infant, which appears to be excited solely in this manner. An inspiratory effort is often made, as soon as the face has emerged from the Vagina of the mother; whilst, on the other hand, if the face be prevented from coming into contact with cool air, the inspiratory

effort may be wanting. When it does not duly take place, it may often be excited by a slap with the flat of the hand upon the nates or abdomen; a fact which shows the special influence of impressions upon the general surface, in rousing the motor impulse in the medulla oblongata, and in causing its transmission to the muscles. The deep inspirations which follow a dash of cold water upon the face, or the descent of the cold douche or of the divided streams of the shower-bath upon the body, or the shock of immersion in the cold plunge-bath, all testify to the powerful influence of such impressions in the adult; and the efficacy of other kinds of irritation of the skin, such as beating with holly twigs, in maintaining the respiratory movements in cases of narcotic poisoning, shows that the required impressions are not restricted to the contact of cold air or water. It seems probable, from various facts, that the presence of venous blood in the arterial capillaries of the system, and the consequent stagnation in the current through them (§ 597), may exert an influence through the Sympathetic system: which may be transmitted, by the copious inosculations of that system with the Par Vagum, to the Medulla Oblongata; and which may there serve as a valuable auxiliary in exciting the respiratory movements.

687. Of the mode in which the impressions, thus transmitted to the Medulla Oblongata, act in exciting the motor impulses which issue from it, nothing is known; but these impulses, directed along the phrenic, intercostal, and other nerves, produce the requisite movements. When the stimulus is unusually strong, various nerves and muscles are put in action, which do not co-operate in the ordinary movements of inspiration; and it may sometimes be observed, that movements are thus excited in parts, which will not act in obedience to the will, being to all appearance completely paralyzed. This fact shows how completely the class of actions in question is independent of the influence of the mind; but we must not lose sight of the control which the mind, especially in the higher classes of animals, possesses over them. Various actions of the respiratory muscles, particularly those of weeping and laughing, are the most direct means of expressing the passions and emotions of the mind; and are involuntarily excited by these. And, again, the respiratory actions are placed to a certain degree under the control of the will; in order that they may be subservient to the production of vocal sounds, and to the actions of speech, singing, &c. The will cannot long *suspend* the respiratory movements; for the stimulus to their involuntary performance soon becomes too powerful to be any longer resisted. And it is well that it should be so; for if the performance of this most important function were left to our own choice, a few moments of forgetfulness would be productive of fatal results. But it is to the power which the will possesses, of directing and controlling the respiratory movements, that we owe the faculty of producing articulate sounds, and thus of holding the most direct and intimate converse with each other.

688. It is essential for the due performance of the respiratory movements, that the portion of the nervous centres, on which they depend, should be in a state of activity. This is the case, under ordinary circumstances, throughout life. The state of perfect quiescence, to which the brain is liable, never affects the medulla oblongata; and the respiratory movements are consequently kept up with as much regularity and energy (in proportion to the requirements of the system), during our sleeping, as during our waking hours. But if any cause induce torpidity of the medulla oblongata, the respiratory movements are then retarded, or even suspended altogether; and all the consequences of the cessation of the aëration of the blood speedily develop themselves (§ 706). This is seen in apoplexy; when the pressure, or other cause of suspended activity, which at first affected the brain alone, gradually propagates its influence downwards. The same is the case in narcotic poisoning; in which also the brain is the first to be affected, and may suffer alone; but if the noxious influence be propagated to the medulla oblongata, it manifests itself in the retardation of the respiratory movements, and, when sufficiently powerful, in their complete suspension. Under such circumstances, it is requisite to resort to all possible means of keeping up the respiratory movements; and when these fail, artificial respiration may be successfully employed. For if, by such means, the circulation can be prevented from failing for a sufficient length of time, the ordinary processes of nutrition go on, the poisonous matter is gradually decomposed or eliminated by the secreting organs; and the nervous centres resume their usual functions. A torpid condition of the medulla oblongata, inducing a retardation of the respiratory movements, seems to be one of the morbid conditions attendant upon typhoid fever; and probably depends in the first instance upon a disordered state of the blood, which does not exert its usual vivifying influence. In such cases, the proportion of the respiratory movements to the pulse sinks as low as 1 to 6, or even as 1 to 8; and thus the due aëration of the blood is not performed, and its stimulating properties are still further diminished.

4. *Chemical Phenomena of Respiration.*

689. Having now fully considered the means, by which the Atmosphere and the blood are brought into relation in the lungs, we have to examine into the results of their mutual action. It will be remembered that the Atmosphere contains about 21 per cent. of Oxygen to 79 of Nitrogen, by *measure;* or 23 parts of Oxygen to 77 of Nitrogen, by *weight.* The Nitrogen seems to perform no other part than that of diluting the oxygen; at least the results of the most recent and exact experiments render it very doubtful, whether (in the respiration of Man at least) any change is effected in the nitrogen of the inspired air. The leading phenomenon of respiration, is the removal of a certain quantity of Oxygen from the air, and its replacement by Carbonic

acid. The relative proportions, which the oxygen absorbed, and the carbonic acid exhaled, bear to one another, have been variously stated. The most recent and trustworthy experiments on this subject (those of Brunner and Valentin) lead to a very interesting result. According to the law of the "mutual diffusion" of gases, the volumes of any two gases, that pass through a porous medium to mingle with each other, will be respectively in the inverse proportion to the square roots of their specific gravities. Now when oxygen is on the outer side, and carbonic acid on the inner, the volume of oxygen that passes inwards will exceed that of the carbonic acid that passes outwards; and this in the proportion of 1174 to 1000. This calculation, deduced from the relative densities of the two gases, corresponds so closely with the actual result of experiments upon the respiration of Man, that it seems next to certain, that the interchange of oxygen and carbonic acid, which occurs between the air and the blood in the lungs, takes place in exact accordance with this law of mutual diffusion.

690. Now Carbonic Acid contains precisely its own volume of oxygen; consequently, of the 1174 parts of oxygen absorbed, 1000 are excreted again by the lungs in the form of carbonic acid; and there remain 174, or nearly 15 per cent., to be accounted for in other ways. It is certain that some of this enters into combination with the sulphur and phosphorus of the original components of the body; and converts these into sulphuric and phosphoric acids; and the remainder must enter into other chemical combinations, very probably uniting with the hydrogen of the fatty matter, to form part of the water which is exhaled from the lungs.

691. It is difficult to form an exact estimate of the actual quantity of Carbon, thrown off from the lungs in the form of Carbonic Acid during any lengthened period; since the amount disengaged during experiments carried on for a limited time, cannot, for many reasons, be taken as affording a fair average. Thus the quantity will vary with the external temperature, with the state of previous rest or activity, with the length of time that has elapsed since a meal, and particularly with the general development of the body. The amount of carbonic acid exhaled is greatly increased by external cold; as is shown in the results of such experiments as the following. Small Birds and Mammals having been enclosed in a limited quantity of air, for the space of an hour, at ordinary temperatures, the quantity of carbonic acid they produced was noted. The experiment was then repeated at a temperature nearly approaching that of the body; and was performed a third time at a temperature of about 32°. The following are the comparative amounts.

	Temp. 59°—68°. Grammes.	Temp 86°—106°. Grammes.	Temp. about 32°. Grammes.
A Canary	0·250	0·129	0·325
A Turtle-dove	0·684	0·366	0·974
Two Mice	0·498	0·268	0·531
A Guinea-pig	2·080	1·453	3·006

Thus it would appear that the quantity of carbonic acid exhaled between 86° and 106° is not much more than *half* of that which is exhaled between 59° and 68°; and is only about *two-fifths* of that which is given off at 32°.

692. The quantity of carbonic acid exhaled during exercise, and for a certain time after it, and also after a full meal, is considerably increased; whilst on the other hand, it is greatly diminished during sleep. Thus a person who was excreting 145 grains of carbon per hour, whilst fasting and at rest, excreted 165 after dinner, and 190 after breakfast and a walk; whilst he only excreted 100 during sleep. The variation with the general development of the body, and also with the sex and age, is considerable. Thus, the exhalation is almost always greater in males than in females of the same age, at every period of life except childhood. In males, the quantity increases regularly from eight to thirty years of age, remaining nearly stationary until forty;—thus it averages 77·5 grains of carbon per hour at eight years; 135 grains at fifteen; 176·7 grains at twenty; and 189 grains between thirty and forty. Between forty and fifty, there is a well-marked diminution, the average being then 156 grains; and the diminution continues up to extreme old age, when the amount exhaled scarcely exceeds that which is extricated at ten years of age; thus, between sixty and eighty, it was 142·5 grains; and in a man of a hundred and two, it was only 91·5 grains. These average results, however, are widely departed from in individual cases; an extraordinary development of the muscular system being always accompanied by a high rate of extrication of carbon; and vice versâ. Thus a man of remarkable muscular vigour, whose age was twenty-six years, exhaled 217 grains of carbon in an hour; a robust man of sixty exhaled 209·4 grains; and an old man of ninety-two, who in his younger days had possessed uncommon muscular powers, and who preserved a remarkable degree of energy, still consumed at the rate of 151 grains per hour. On the other hand, a man of slight muscular development, at the age of forty-five, only exhaled 132 grains; and another at the age of seventy-six, only 92·4 grains.

693. In *females*, nearly the same proportional increase goes on, up to the time of puberty; when the quantity abruptly ceases to increase, and remains stationary so long as menstruation continues regular. The average quantity of carbonic acid exhaled by girls nearly approaching puberty, is about 100 grains per hour; and it remains at this standard until nearly the close of menstrual life. At the period of the cessation of the catamenia, it undergoes a perceptible increase; the average, between forty and fifty years of age, being about 130 grains per hour; and the quantity exhaled in a woman of great muscular development, and of forty-four years of age, rising to 152·4 grains in an hour. After the age of fifty, or thereabouts, the quantity decreases, as in men. It is remarkable that, during pregnancy, there is the same increase in the exhalation of carbon, as there is after the final cessation of the cata-

menia; and the same takes place, if the menstrual discharge be temporarily suspended, through any other cause.

694. It is obviously difficult, then, to obtain exact estimates, from any experiments conducted for a short time only, of the total amount of carbon thrown off during a lengthened period; since the condition of the individual varies so greatly at different times; and the variation amongst different individuals is so great. Moreover, of the total amount of carbon excreted in a gaseous form, a certain part is undoubtedly set free from the skin; and the proportion of this has not been yet determined. As a means of measuring the whole quantity of carbonic acid set free, without causing the respiratory movements to be performed in any unnatural manner, Prof. Scharing constructed an air-tight chamber, of dimensions sufficient to allow an individual to remain in it for some time without inconvenience; and so arranged, that he could eat and drink, read, or sleep, within it. This was connected with an apparatus, by which the air was continually renewed; and the air drawn off was carefully analyzed in order to determine the quantity of carbonic acid contained in it. The average per hour, in different states, having been ascertained, it was calculated that, allowing seven hours for sleep in adults, and nine hours for children, the *total* amount of carbon consumed in the twenty-four hours was as follows:—

No.		Weighing.	Grains.		Oz. Troy.
1.	A male, aged thirty-five,	131 lbs.	3380	or	7·0
2.	A male, aged sixteen,	115½ lbs.	3450	or	7·2
3.	A soldier, aged twenty-eight,	164 lbs.	3692	or	7·7
4.	A girl, aged nineteen,	111 lbs.	2555	or	5·3
5.	A boy, aged nearly ten,	44 lbs.	2050	or	4·3
6.	A girl, aged ten,	46 lbs.	1938	or	4·0

695. This estimate is perhaps rather too low; as it does not take sufficient account of the great increase, which is produced by exercise. Another method has been adopted by Prof. Liebig; who endeavoured to ascertain the total amount of carbon excreted from the body in the form of carbonic acid, by comparing the amount of carbon taken in as food, with that contained in the feces and urine; the difference being set down to the account of respiration. His estimate amounts to the very large sum of 13·9 oz. of solid carbon per day, which he considers to be thus set free by the lungs and skin; but this is almost certainly above the truth. The observations were made upon a body of soldiers who were subjected to severe daily exertion; and they were far from being exactly conducted, many of the items being set down by guess only, whilst of others no account whatever was taken. We may perhaps consider 10 or 11 oz. as more nearly representing the amount of carbon consumed by adult men exposed to severe exertion; whilst from Prof. Scharling's experiments it may be inferred, that from 7 to 8 oz. of carbon are thrown off during the twenty-four hours by the lungs and skin of adult men not using much active exer-

tion; to which another ounce or two may be added, as the increased quantity excreted during moderate exercise.—On the other hand, from experiments made upon the quantity of carbonic acid exhaled from the lungs alone during a given time, it would appear that the *pulmonary* excretion of carbon amounts to between 5½ and 8 oz. in the twenty-four hours; and the difference may be partly set down to the account of the *cutaneous* respiration.

696. If we assume 10 oz. or 4800 grains of solid carbon as the total amount excreted from the lungs and skin of a male adult, using active exercise in the course of twenty-four hours, we find that the volume of carbonic acid thus generated must be nearly 37,000 cubic inches, or more than 21 cubic feet. Of this about 16 cubic feet are probably extricated from the lungs. But it is probable that about 10 cubic feet per day is near the ordinary average. Now it has been ascertained, that the whole quantity of air which passes through the chest during that time under similar circumstances, is about 266 cubic feet; so that the proportion of carbonic acid contained in the expired air seems to average about 4 per cent. It is certain, however, that this proportion may rise much higher; particularly when the respiratory movements are slowly and laboriously performed. Now in order that the blood should be properly aërated, it is requisite that the air should contain no previous impregnation of carbonic acid; since the diffusion of even a moderate per centage of that gas through the inspired air, seriously impedes the exhalation of more. Thus it was found by Messrs. Allen & Pepys, that when 300 cubic inches of air were respired for three minutes, only 28½ inches of carbonic acid (or somewhat more than 9 per cent.) were present in it; though the rate of its production in a parallel experiment, in which fresh air was taken in at each inspiration, was 32 cubic inches per minute, or 96 cubic inches in three minutes. That it is not the deficiency of oxygen, but the presence of carbonic acid in the inspired air, which impedes the free aëration of the blood, is proved by the recent experiments of Dr. D. B. Reid; who has shown that an animal may be kept alive in a limited quantity of air, until nearly all its oxygen is exhausted, if an effectual provision be made for drawing off the carbonic acid as fast as it is generated.

697. An animal thus made to breathe an atmosphere, which contains less than its normal proportion of oxygen, resembles one which is made to breathe a rarefied atmosphere, such as that which exists on the summits of high mountains. All persons who have made such ascents, have experienced the insufficiency of rarefied air to sustain the degree of respiration required for active exertion. As long as the body remains at rest, no inconvenience is perceived; but as soon as the muscular system is put into action, the insufficiency of the supply of oxygen is manifested by the feeling of distress and languor; which becomes so severe, that the individual, if unused to such ascents, is obliged to stop and take breath at every few steps. The necessity for doing so will be easily understood, when it is remembered that when the *pressure* of the atmosphere is reduced to *half* its usual

amount, the *bulk* of a given weight of air will be *twice* as great as at the surface of the earth, or the *same* measure will weigh only *half* as much. Consequently, when the chest is completely filled with air, the real quantity of oxygen included in it, is only half of that, which is drawn in by a corresponding inspiration at the earth's surface.

698. Although an impregnation of carbonic acid, to the amount of seven or eight per cent., would be required to destroy life in most warm-blooded animals, yet a much smaller proportion is sufficient to produce very injurious results. Thus the discomforts occasioned by the presence of a crowded audience in a church, lecture-room, or theatre, which is not provided with sufficient ventilation, are due in great part to the continued respiration of air, which becomes loaded in the course of an hour or two with carbonic acid gas, to the amount of from one-half to two per cent.,—as has been ascertained both by direct experiment, and by calculation. And there can be little doubt, that the habitual respiration of such air, in the narrow and noisome dwellings of the poor, or in crowded factories and workshops, has a tendency to produce, both directly and indirectly, much loss of physical and mental vigour, and also to blunt the acuteness of the moral feelings.

699. Having thus considered the changes produced by the Respiratory function, in the *air* submitted to it, we have next to inquire into converse series of change effected by it in the *blood*. The nature of these cannot be well stated with precision; as they have not yet been fully determined. It was formerly supposed, that the venous blood arrives at the lungs charged with carbon; and that this carbon is united with the oxygen of the air, in the lungs themselves. Numerous facts, however, go to prove, that the blood comes to the lungs charged with carbonic acid; and that it gives out this ready formed, and receives oxygen in its stead. Thus it has been already shown, that there is a positive disappearance of oxygen; more of that element being withdrawn from the atmosphere, than is restored to it in the condition of carbonic acid; so that we know that the surplus must be received into the blood. Moreover, the quantity of oxygen absorbed exactly replaces the quantity of carbonic acid set free, according to the law of "mutual diffusion;" which could scarcely be the case, unless the latter were contained in the blood already formed. Further, cold-blooded animals may be made to breathe nitrogen or hydrogen for a sufficient length of time, to cause a large quantity of carbonic acid to be disengaged; and this must have been brought to the lungs ready formed, since no oxygen was present there to generate it. Lastly, it can be shown by experiment, that oxygen, carbonic acid, and nitrogen exist in a free state in blood, arterial as well as venous; but that the proportion of oxygen is greater in arterial than in venous blood, whilst that of carbonic acid is less. The following table expresses the per centage of each kind of gas in the two sorts of blood respectively; as deduced from the experiments of Magnus.

	Arterial Blood.	Venous Blood.
Carbonic acid	62·3	71·6
Oxygen	23·2	15·3
Nitrogen	14·5	13·1

Thus it appears that the quantity of nitrogen is very nearly the same in both, as would be anticipated from what has been already stated in regard to its non-participation in the respiratory process; whilst about one-third of the free oxygen of arterial blood disappears during its circulation in the systemic capillaries, to be replaced by an equivalent amount of carbonic acid ; and a converse change takes place in the pulmonary capillaries, this additional portion of free carbonic acid being set free, and replaced by oxygen.

700. Thus it is evident, that a part of the change effected in the blood consists in an alteration in the proportion of the gases which always exist in it, either entirely free, or in a state of such loose combination that they can be removed by the air-pump. But it cannot be doubted, that a portion of the effect consists in the oxidation of the proteine of the fibrinous constituent; since the fibrin of arterial blood possesses properties that distinguish it from that of venous. And it seems probable, also, for the reasons formerly stated, that the hematosine of the red corpuscles undergoes a change under the influence of oxygen in the lungs, and a converse change in the systemic capillaries, where it is subjected to the influence of carbonic acid. This much appears tolerably certain :—that a part of the oxygen imbibed in the lungs, is appropriated to the oxidation of the matters set free by the decomposition of the solid tissues;—whilst another part enters into combination with fatty, saccharine, or farinaceous matters, existing in the blood itself, and destined to be carried off in the form of carbonic acid and water, without ever entering into the composition of the solid fabric. The relative amounts of carbonic acid formed in these two modes, vary in different animals, and in different states of the same individual; for a man in a warm atmosphere, taking a moderate amount of exercise, may thus set free, by the waste of his muscular and other tissues, a sufficient quantity of carbon, for the maintenance of his animal heat by its union with oxygen; but this is far from being sufficient, when a larger amount of heat must be evolved, to sustain the temperature of the body in a colder climate.

701. The blood parts in the lungs with a very large amount of moisture; for the inspired air is always saturated with fluid, as soon as it reaches the air-cells; and, as it is heated at the same time to about 98°, it thus receives a considerable addition, even if it were previously charged with as much as it could contain at a lower temperature. The total quantity of fluid thus disengaged will vary, therefore, with the amount previously contained in the atmosphere; being greater as this was less, and vice versâ; the expired air being always charged with as much as it can contain at the temperature of 98° or 99°. It cannot be doubted, that a great part of this water is a simple

exhalation of that which has been absorbed; but, on the other hand, it seems probable that a portion of it may be actually formed in the system, by the union of a portion of the oxygen absorbed in the lungs, with the hydrogen of the combustible matters of the blood. In the various forms of saccharine and farinaceous aliments, the proportions of hydrogen and oxygen are such as would of themselves form water, when the carbon is withdrawn; but in oily and fatty matters, the proportion of oxygen is far too small thus to neutralize the hydrogen; and it seems likely that, by their oxidation in the blood, as by their combustion elsewhere, water is actually generated by the union of atmospheric oxygen with their hydrogen, whilst carbonic acid is produced by its union with their carbon.

702. Along with the water thus extricated from the lungs, a certain amount of organic matter is set free. If the fluid be collected in a closed vessel, and be exposed to warmth, a very evident putrid odour is exhaled from it; and if the expired air be made to pass through sulphuric acid, that liquid is coloured red. Every one knows that the breath itself possesses, occasionally in some persons, and constantly in others, a fetid taint; when this does not proceed from carious teeth, ulcerations in the air-passages or lungs, or other similar causes, it must result from the excretion of the odorous matter, in combination with watery vapour, from the pulmonary surface. That this is the true account of it seems evident, from the analogous phenomenon of the exhalation of turpentine, camphor, alcohol, and other odorous substances, which have been introduced into the venous system, either by natural absorption, or by direct injection; and also from the suddenness with which the odour manifests itself, when the digestive apparatus is slightly disordered.

5. *Effects of Insufficiency, or Suspension, of the Aërating Process.*

703. The change which the Blood undergoes, by being brought into relation with atmospheric air in the respiratory organs, is so important to life, that the entire suspension of it inevitably produces a fatal termination, at no remote period; and if it be insufficiently performed, various disorders in the system are nearly sure to manifest themselves. The state which is induced by the entire suspension of the aërating process, is termed Asphyxia; a word which literally means the absence of pulse, and would be applicable, therefore, to the stoppage of the circulation from any cause; though it is usually employed to designate the particular condition, resulting from suspended respiration. Asphyxia may be produced in aquatic animals, as well as in those which breathe air, by cutting them off from the influence of the atmosphere; for if a Fish be placed in water from which the air has been expelled by boiling, it is precisely in the condition of an air-breathing animal placed in a vacuum, since it has no power of obtaining oxygen by decomposing the water it inhabits, and is entirely dependent for the aëration of its blood, upon the air that is

absorbed by the liquid. Again, if a fish be placed in water impregnated with carbonic acid, its death is nearly as instantaneous as that of an air-breathing animal immersed in an atmosphere of that gas.

704. Asphyxia may result from a great variety of causes. Thus there may be a mechanical obstruction to the entrance of air through the trachea; as in hanging, strangulation, or drowning; or as in occlusion of the aperture of the glottis, by œdema of its lips, or by the presence of a foreign body in the larynx. Or, again, the passage may be perfectly free, and yet no air may enter, in consequence of some obstacle to the performance of the respiratory movements. This obstacle may be mechanical; as when a quantity of earth has fallen round the body, in such a manner as completely to prevent the distension of the chest and abdomen. Or it may result (and this is a most frequent occurrence) from torpidity or complete inactivity of the ganglionic centre, which is concerned in the respiratory actions; or from interruption to the transmission of its influence along the nervous trunks. Further, when there is no obstacle to the free ingress or egress of air, Asphyxia may be produced by the want of oxygen in the atmosphere that is respired, or by the presence of carbonic acid in too large an amount. And the presence of other gases, which exert a directly poisonous influence on the blood,—such as sulphuretted hydrogen,—produces a state, which may be included under the same general description.

705. Now when, from any of these causes, the free exchange of carbonic acid for oxygen in the pulmonary capillaries is checked, the first effect of the interruption appears to be, the stagnation of the blood in the pulmonary capillaries. This stagnation is evidently due, not to any deficiency of power in the heart; for that organ is not yet affected; but to the insufficiency of the heart's power, acting alone, to drive the blood through the pulmonary capillaries; the force which should be generated by chemical changes in them (§ 598), being deficient. The stagnation is not, however, complete at first; since the quantity of oxygen contained in the lungs is sufficient to produce an imperfect arterialization of the blood; and the blood thus partially changed is transmitted to the left side of the heart, and is thence propelled to the system. Owing to its half-venous condition, it cannot exert its usual stimulating influence on the tissues, especially the muscular and nervous; and their powers are consequently weakened. For the same reason, it does not receive its usual auxiliary force in the systemic capillaries (§ 599); since the changes, which it ought to undergo in them, can only be partially performed.

706. As the air included in the lungs loses more and more of its oxygen, and is more and more charged with carbonic acid, the aëration of the blood in the pulmonary capillaries becomes more and more imperfect; the quantity of blood which is allowed to return to the heart is gradually diminished, and its condition becomes more and more venous; and at last, the pulmonary circulation is altogether suspended. From the relation which the respiratory circulation bears to

the systemic, in all the higher classes of animals, save Reptiles, it follows that the systemic circulation must in like manner be brought to a stand. The venous blood accumulates in the pulmonary artery, in consequence of the obstruction of its capillaries; it distends the right cavities of the heart; and the accumulation extends to the venous system of the body in general, especially affecting those organs which naturally receive a large quantity of venous blood, such as the liver and spleen. The arterial system, on the other hand, is emptied in a corresponding degree; nearly all its blood having passed through the systemic capillaries; and no fresh supplies being received from the heart. From this deficiency, and from the venous character of the blood which the systemic arteries *do* contain, it results that the nervous and muscular systems lose their power; insensibility comes on, at first accompanied with irregular convulsive movements; but in a short time there is a total cessation of all movement except that of the heart; and the pulsations of that organ become feebler and feebler, until they cease altogether. The immediate cause of the cessation of the heart's action appears to be different on the two sides. Both are equally affected by the want of arterial blood in the capillaries of their own substance; but the right side suffers from over-distension, which produces a sort of paralysis of its muscular tissue; whilst the left side retains its contractility, but is not excited to contraction, for want of the stimulus of arterial blood in its cavities.

707. In those warm-blooded animals, which are not endowed with any special provision for enabling them to sustain life during the prolonged suspension of the respiratory process, insensibility and loss of voluntary power almost invariably supervene within a minute and a half, after the admission of air to the lungs has been entirely prevented; though the respiratory efforts and convulsive actions, which are dependent upon the medulla oblongata and spinal cord, may continue for a minute or two longer. The circulation generally comes to a complete stand within ten minutes at farthest.—The chief exceptions are in the case of diving animals, which are provided with large arterial and venous reservoirs, that serve to maintain the circulation during a prolonged suspension of the respiratory process; for the arterial plexuses being ordinarily filled, they afford a supply of aërated blood to the systemic capillaries, when other blood is wanting; and the reservoirs connected with the venous system, which were previously empty, receive this blood, and prevent it from exercising undue pressure on the heart. To such an extent is this provision carried in some animals, that the Whale has been known to remain under water for an hour. Another exception exists in the case of hybernating Mammals, which are reduced for a time to the condition of cold-blooded animals; and which can, like the latter, sustain a prolonged suspension of the aërating process. And there is reason to believe that, in the state of Syncope or fainting,—in which the circulation is already reduced to a very low amount, in consequence

of a partial failure in the heart's power, all the functions of the body being nearly suspended, and the demand for aëration being consequently very small,—the respiration may be suspended for a long period, even in the Human subject, without fatal results. Thus more than one case has been credibly recorded, in which recovery has taken place after complete submersion for more than three-quarters of an hour; and it is probable that, in these instances, a state of Syncope came on at the moment of immersion, through the influence of mental emotion, or of concussion of the brain.

708. In the restoration of an animal from the state of Asphyxia, it is above all things of importance to renew the air in the lungs; for in this way the blood in the pulmonary capillaries will be aërated; the capillary circulation will be re-established; the right side of the heart will be relieved of its excessive load of venous blood; and the left side will receive the stimulus of a fresh supply of arterial blood; so that, if its movements have not ceased altogether, it may be speedily restored to due activity. At the same time, the temperature of the body should be kept up by artificial warmth; and the circulation in the skin should be excited by friction. Where no other means are at hand for introducing pure air into the lungs (of which means the application of galvanism along the course of the phrenic nerve, so as to produce contraction of the diaphragm, will probably be the most effectual), the object may be attained by forcibly compressing the trunk on all sides, so as to empty the lungs as much as possible, and then allowing the chest to dilate again, by the elasticity of its walls. In this manner, a large proportion of the carbonic acid may be expelled, and a considerable proportion of the fresh air introduced, in the course of a few minutes. If air be blown into the lungs by the bellows, great care must be taken to prevent the employment of too much force, which is likely to produce rupture of the air-cells.

709. Now when, from the more prolonged action of various causes, that impede the due performance of the respiratory function, the aëration of the blood in the lungs is insufficient for health, though not such as to produce a complete stagnation of the movement, a variety of results may follow; of which some, or others, will manifest themselves according to the condition of the general system, and the peculiarities of the individual. Thus deficient respiration has an undoubted tendency to produce, in some persons, what is termed "fatty degeneration" of the liver; the fatty matter, which ought to be eliminated by the respiratory process, being thrown upon the liver to be separated by it, and distending its cells (§ 723). And there is reason to believe, that a similar cause may produce fatty degeneration of the kidney, in cases where there is a peculiar determination of blood to that organ. Again, the due elaboration of the fibrin of the blood is undoubtedly prevented by an habitually deficient respiration; and various diseases, which result from the imperfect performance of this elaboration, consequently manifest themselves. The *Scrofulous* dia-

thesis is thus frequently connected with an unusually small capacity of the chest.—Further, an habitual deficiency of respiration may impede, though it does not check, the circulation in the lungs; and thus a tendency arises, in various pulmonary diseases, to an overloading of the pulmonary arteries, to a dilatation of the right cavities of the heart, and to a congestion of the venous system in general, as marked by lividity of the surface, by venous pulsation, &c. This state may result, not merely from obstruction in the lungs themselves, but from deficiency of the respiratory movements, consequent upon torpidity of the medulla oblongata (as in apoplexy and narcotic poisoning), or upon partial interruption of the nervous circle requisite for all reflex movements. Thus when the par vagum is divided, the number of respiratory movements is greatly diminished, and a partial stagnation of the blood in the lungs is the result. The same happens in certain forms of typhoid fever, in which the respiratory movements are preternaturally slow, in consequence of torpidity of the medulla oblongata. Now in this state, an effusion of the watery part of the blood into the air-cells of the lungs (as in other cases of obstructed circulation) is very liable to occur; and when the lungs are thus loaded with fluid, the respiratory process is still more impeded, and the disorder has thus a tendency to increase itself.

CHAPTER IX.

OF SECRETION.

1. *Of the Secreting process in general; and of the Instruments by which it is effected.*

710. We have seen that, in the process of Nutrition, the circulating current not only *deposits* the materials, which are required for the renovation of the solid tissues; but also *takes back* the substances, which are produced by the decay of these, and which are destined to be thrown off from the body. We have also seen that it supplies the materials of certain fluids, which are separated from it to effect various purposes in the economy;—such as the Salivary and Gastric fluids, which have for their office to assist in the reduction of the food. Now the process, by which the fluids of the latter kind are separated from the Blood, is precisely the same in character as that, by which the products of decay are eliminated from it; and the structure of the organs concerned in the two is essentially the same. Hence both processes are commonly included under the general term *Secretion*, which simply denotes *separation.* Considered in its most general point of view, this designation may be applied to *every* act, by which sub-

stances of any kind are *separated* from the blood. Thus the function of the floating cells, which are concerned in the production of Fibrin (§ 213), may be termed one of secretion; because they draw from the blood a supply of Albumen, upon which their converting action is exercised; but as the product of their operation is returned to the blood again, and is employed for higher purposes in the economy, the process is usually termed Assimilation. In the same manner, the elaborating action of the Lymphatic Glands, with the Spleen, Thymus Gland, &c., is not usually termed Secretion; since, although it is exercised upon matter drawn from the blood, the product appears to be delivered back into the circulating current, through the medium of the Lymphatic System (CHAP. V). With much more justice, however, the process of Respiration may be regarded as one of Secretion; for it consists, as we have seen, in the constant elimination of a substance from the blood, which cannot be retained in it without the most injurious consequences.

711. There is an important difference in the characters of the principal products of the Secreting process; which is connected with the purposes that are to be answered by their separation. Some of these products are *altogether different* from the ordinary constituents of the animal fabric, and from the materials which the blood supplies for the nutrition of these. So different are they, that their presence in the circulating current has an injurious effect; and the great object of their separation is the maintenance of the purity of the blood. These poisons, for such they may be considered, are generated in the system by the decay and decomposition to which its several parts are liable; and they are just as noxious to it, as if they were absorbed from without. We have seen that the retention of Carbonic acid in the blood for even a few minutes is fatal; both by putting a stop to the circulation, and by acting unfavourably upon the substance of some of the most important organs in the body. The same fatal result attends the retention of Urea and of Biliary matter, which are among the other products of the decomposition of the tissues; but, although as certain, it is not so speedy, because the general circulation is not affected by the loss of secreting power on the part of the Kidneys and the Liver, and because the accumulation of the noxious matter is slower.—On the other hand, the ingredients that are met with in those secreted fluids, which are destined to answer some purpose in the economy, almost invariably bear a close correspondence with the ordinary materials of the blood. Thus in the Salivary, Gastric, Pancreatic, and Lachrymal fluids, the principal part of the solid matter consists of the saline and of the albuminous constituents of the blood,—the latter in a more or less altered condition. In Milk, again, we trace the ordinary constituents of the blood, with very little change. Thus it appears, that the separation of *these* fluids is not required so much to maintain the Blood in a state of purity, as to supply what is needed for some subsequent operation in the economy; and hence, if the secreting process be interrupted, in the case of any one of them, the

suspension has usually no further effect, than that of disturbing the process to which the fluid is usually subservient. If the secretion of Gastric fluid be checked, for example, under the influence of strong mental emotion, the Digestive operation is prevented from taking place.

712. The essential character of the true *Secreting* operation seems to consist,—not in the nature of the action itself, for this is identical with those of Assimilation and Nutrition, being (as we have seen, § 239), a process of cell-growth,—but in the position in which the cells are developed, and the mode in which the products of their action are afterwards disposed of. Thus the cells at the extremities of the intestinal Villi (§ 241), the cells of which the Adipose tissue is made up (§ 259), and the cells of which the greater part of the substance of the Liver is formed (§ 239), all have an attraction for fatty matter; and draw it from the neighbouring fluids, at the expense of which they are developed, to store it up in their own cavities. But the cells of the first kind, when they have come to maturity, set free their contents, which are delivered to the absorbent vessels, to be introduced into the circulating current:—those of the second kind seem more permanent in their character, and retain their contents, so as to form part of the ordinary tissues of the body, until they are required to give them up for other purposes, when the matters, which they have temporarily separated from the circulating current, are restored to it again without change;—and the cells of the third class, when *they* liberate their contents (which they are continually doing), cast them forth into the hepatic ducts, by which they are carried into the intestinal canal, whence a portion of them at least is directly conveyed out of the body.

713. It is, then, in the *position* of the Secreting cells,—which causes the product of their action to be delivered upon a *free surface*, com municating, more or less directly, with an external outlet,—that their distinctive character depends. All the proper *Secretions* are thus either poured out upon the exterior of the body, or into cavities provided with orifices that lead to it. Thus we shall see that a considerable quantity of solid matter, and a very large quantity of fluid, of which it is desirable that the system should be freed, are carried off from the Cutaneous surface. Another most important secretion, containing a large quantity of solid matter, and serving also to regulate the quantity of fluid in the body,—namely, the Urinary,—is set free by a channel expressly adapted to convey it directly out of the body. The same may be said of the Mammary secretion; which is separated from the blood, not to preserve *its* purity, nor to answer any purpose in the economy of the individual, but to afford nutriment to another being. And of the matters secreted by the very numerous glandulæ situated in the walls of the intestinal canal, a great part are obviously poured into it for no other purpose, than that they may be carried out of the body by the readiest channel.

714. The cells covering the simple membranes that form the free surfaces of the body, whether external or internal, are all entitled to

be regarded as *secreting* cells; since they separate from the blood various products which are not again to be returned to it. But the secreting action of some of these seems to have for its object the *protection* of the surface; thus the epidermic cells secrete a horny matter, by which density and firmness are imparted to the cuticle; whilst by the epithelial cells of the Mucous Membrane of the alimentary canal, and of other parts, their protective Mucus seems to be elaborated. But in general we find that special organs, termed *Glands*, are set apart for the production of the chief secretions; and we have now to consider the essential structure of these organs, and the mode of their operation.—A true Gland may be said to consist of a closely packed collection of follicles, all of which open into a common channel, by which the product of the glandular action is collected and delivered. The follicles contain the secreting cells in their cavities; whilst their exterior is in contact with a network of blood-vessels, from which the cells draw the materials of their growth and development (Fig. 90). In any one of the higher animals, we may trace out a series of progressive stages of complexity, in the various glands included within their fabric; and in following any one of the glands, that attain the highest degree of development (such as the Liver or Kidney), through the ascending scale of the Animal series, we should trace a very similar gradation from the simplest to the most complex form.

715. That there is nothing in the *form* or *disposition* of the components of the glandular structure, which can have any influence upon the character of the secretion it elaborates, is evident from the fact, that the very same product,—*e. g.*, the Bile, or the Urine,—is found to issue from nearly every variety of secreting structure, as we trace it through the different groups of the Animal kingdom. The peculiar power, by which one organ separates from the blood the elements of the Bile, and another the elements of the Urine, whilst a third merely seems to draw off a certain amount of its albuminous and saline constituents, is obviously the attribute of the ultimate secreting cells, which are the real agents in the secreting process (§ 239). *Why* one set of cells should secrete bile, another urea, and so on, we do not know; but we are equally ignorant of the reason for which one set of cells converts itself into Bone, another into Muscle, and so on. This variety in the endowments of the cells, by whose aggregation and conversion the fabric of the higher Animals is made up, is a fact which we cannot explain, and which must be regarded (for the present, at least), as one of the "ultimate facts" of Physiological Science.

716. Passing by the extended membranous surfaces, and the protective cells with which they are covered, we find that the simplest form of a secreting organ is composed of an *inversion* of that surface, into a series of follicles, which discharge their contents upon it by separate orifices. Of this we have an example in the *gastric* follicles, even in the higher animals; the apparatus for the secretion of the Gastric fluid never attaining any higher condition than that of a

series of distinct follicles, lodged in the walls of the stomach, and pouring their products into its cavity by separate apertures. In Fig.

Fig. 103.

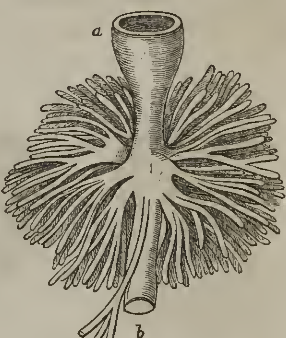
Glandular follicles in ventriculus succenturiatus of Falcon.

Fig. 104.

Origin of the Liver from the intestinal wall, in the embryo of the Fowl, on the fourth day of incubation:—*a*, heart; *b*, intestine; *c*, everted portion giving origin to liver; *d*, liver; *e*, portion of yolk-bag.

103 is represented a portion of the Ventriculus succenturiatus of a Falcon; in which the simplest form of such follicles is seen. A somewhat more complex condition is seen in some of the Gastric follicles of the Human stomach (Fig. 75); the surface of each follicle being further extended by a sort of doubling upon itself, so as to form the commencement of secondary follicles, which open out of the cavity of the primary one.—Now a condition of this kind is common to *all* glands, in the first stage of their evolution; and in this stage we meet with them, either by examining them in the lowest animals in which they present themselves, or by looking to an early period of their embryonic development in the highest. Thus, for example, the Liver consists, in certain Polypes and in the lowest Mollusca, of a series of isolated follicles, lodged in the walls of the stomach, and pouring their product into its cavity by separate orifices; these follicles being recognized as constituting a biliary apparatus, by the colour of their secretion. And in the Chick, at an early period of incubation, the condition of the Liver is essentially the same with the preceding; for it consists of a cluster of isolated follicles, not lodged in the walls of the intestine, but clustered round a sort of bud or diverticulum of the intestinal tube, which is the first condition of the

Fig. 105.



Rudimentary Pancreas from Cod;—*a*, pyloric extremity of stomach; *b*, intestine.

Fig. 106.

Mammary Gland of Ornithorhyncus.

hepatic duct, and into which they discharge themselves (Fig. 104). So, again, the Pancreas first presents itself in the condition of a group of prolonged follicles, or *cœca*, clustered round the commencement of the intestinal tube (Fig. 105); which is its permanent condition in many Fishes. And the Mammary Gland possesses an equally simple structure in the lowest of all the Mammalia (to which group it is restricted ;—namely, in the Ornithorhyncus (Fig. 106).

717. The next grade of complexity is seen, where a cluster of the ultimate follicles open into one common duct, which discharges their product by a single outlet; a single gland often containing a number of such clusters, and having, therefore, several excretory ducts. A good example of such a condition, in which the clusters remains isolated from one another, is seen in the Meibomian glands of the eyelid (Fig. 107); each of which consists of a double row of follicles, set upon a long straight duct, that receives the products of their secreting action, and pours them out upon the edge of the eyelid. And of the more complex form, in which a number of such clusters are bound together in one glandular mass, we have an illustration in the accessory glands of the genital apparatus, in several animals, which discharge their secretion into the urethra by numerous outlets (Fig. 108); or in the Mammary glands of Mammalia in general, the ultimate follicles of which are clustered upon ducts that coalesce to a

Fig. 107.

Meibomian glands of upper lid of new-born infant.

Fig. 108.

Portion of Cowper's gland, from Hedgehog; the follicles distended with air.

Fig. 109.

Lobule of Lachrymal Gland; from fœtal sheep.

considerable extent, though continuing to form several distinct trunks even to their termination. Such glands may be subdivided, therefore, into *glandulæ* or *lobules*, that remain entirely distinct from each other (Fig. 109).—In the highest form of Gland, however, all the ducts unite; so as to form a single canal, which conveys away the products of the secreting action of the entire mass. This is the condition in which we find the Liver to exist, in most of the higher animals; also the Pancreas, the Parotid Gland, and many others. In some of these cases, we may still separate the gland into numerous distinct lobules, which are clustered upon the excretory duct and its branches, like grapes upon a stalk; in others, however, the branches

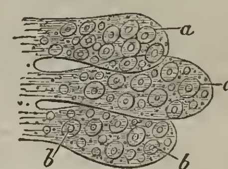
of the excretory duct do not confine themselves to *ramifying*, but *inosculate* so as to form a network, which passes through the whole substance of the gland, and which connects together its different parts, so as to render the division into lobules less distinct. This seems to be the case in regard to the Liver of the higher Vertebrata.

718. Whatever degree of complexity, however, prevails in the general arrangement of the elements of the Glands in higher animals, these elements are themselves everywhere the same, consisting of *follicles* that enclose the real secreting cells (Figs. 110 and 111). Now from the history of the development of Glands in general, it appears that the *follicles* may be considered as *parent cells;* and that the

Fig. 110.

Two follicles from the liver of *Carcinus mænas* (Common Crab), with their contained secreting cells.

Fig. 111.



Ultimate follicles of Mammary gland, with their secreting cells, *a*, *a*;—*b*, *b*, the nuclei.

secreting cells in their interior constitute a *second* generation, developed from the nuclei or germinal spots on the walls of the first. It has been pointed out by Mr. Goodsir, that the continued development and decay of the glandular structure,—in other words, the elaboration of its secretion, may take place in two different modes. In one class of Glands, the parent-cell, having begun to develop new cells in its interior, gives way at one point, and bursts into the excretory duct, so as to become an open follicle, instead of a closed cell: its contained or secondary cells, in the progress of their own growth, draw into themselves the matter to be eliminated from the blood, and, having attained their full term of life, burst or liquefy, so as to discharge their contents into the cavity of the follicle, whence they pass by its open orifice into the excretory duct: and a continual new production of secondary cells takes place from the germinal spot or nucleus, at the extremity of the follicle, which is here a permanent structure. In this form of gland, we may frequently observe the secreting cells existing in various stages of development within a single follicle; their size increasing, and the character of their contents becoming more distinct, in proportion to their distance from the germinal spot (which is at the blind termination of the follicle), and their consequent proximity to the outlet (Fig. 110). In some varieties of such glands, however,—as in the greatly prolonged follicles, or tubuli uriniferi, of the kidney,—the production of new cells does not take place from a single germinal spot at the extremity of the follicle, but from a number of points scattered through its entire length.

719. In the second type of Glandular structures, the parent-cell

does not remain as a permanent follicle; but, having come to maturity and formed a connection with the excretory duct, it discharges its entire contents into the latter, it then shrivels up and disappears, to be replaced by newly-developed follicles. In each parent-cell of a gland formed upon this type, we shall find all its secondary or secreting cells at nearly the same grade of development; but the different parent-cells, of which the parenchyma of the gland is composed, are in very different stages of growth, at any one period,—some having discharged their contents and being in progress of disappearance, whilst others are just arriving at maturity and connecting themselves with the excretory duct; others exhibiting an earlier degree of development of the secondary cells; others presenting the latter in their incipient condition; whilst others are themselves just starting into existence, and as yet exhibit no traces of a second generation.—The former seems to be the usual type of the ordinary Glands; the latter is chiefly, if not entirely, to be met with in the Spermatic glands.

2. *Of the Liver.*

720. The Liver is more rarely absent than any other Gland; being discoverable, under some form or other, in all but the very lowest members of the Animal kingdom. Its simple condition in the higher Polypes has been already noticed (§ 716); and it is met with, under an almost equally simple form, in the Star-fish. As we ascend the scale, however, we find it assuming a much greater importance, and presenting a great increase in size. This is particularly the case in the Molluscous classes; and also in the Crustacea,—a class which, in mode of respiration and in general habits, bears a great resemblance to the Mollusca. In nearly all such animals, the Liver makes up a large proportion of the mass of the body. It usually consists of a series of large follicles, which branch out into smaller ones (Figs. 112 and 113),

Fig. 112.

Lobule of Liver of Squilla Mantis; exterior.

Fig. 113.

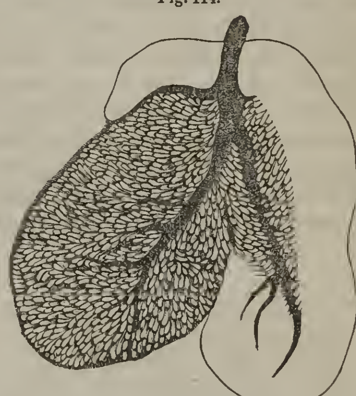
Lobule of Liver of Squilla Mantis cut open.

and of which several open into one excretory duct; but these ducts remain separate, and discharge their contents into the intestine by several distinct orifices.—In Insects and other air-breathing Articu-

lata, however, the Liver is much less developed; and its type remains much simpler. We usually find it consisting of a small number of cæcal tubuli, which open separately into the intestinal canal, just below the stomach. These tubuli are often so long, as to pass several times from one extremity of the visceral cavity to the other, being doubled upon themselves; in other instances, we find that the principal tube or canal is beset with rows of short follicles, somewhat in the manner of Fig. 107. But they never cluster together, so as to form a solid glandular mass. The low development of the liver, in these animals, bears an evident relation with the high development of their respiratory apparatus; whilst, the respiration being comparatively feeble in the aquatic Mollusca and Crustacea, the development of the liver in those classes is enormous.

721. There is much difficulty in ascertaining the mode in which the elementary constituents of the Liver are arranged, in the fully-developed condition of that organ in the higher Vertebrata. At an early period of its development, as already remarked, it may be easily shown to consist, in the Fowl, of a series of distinct cæca, clustered round a projection from the intestinal canal, and opening separately into it (Fig. 104); and it is a peculiarly interesting fact, that this very condition should exist as the permanent form of the Liver, in that curious little fish, the *Amphioxus* or Lancelot, which retains the embryonic type in so many parts of its conformation. In the Tadpole, again, the distinct cæca are very evident (Fig. 114); but here we see that the projection of the intestinal canal, instead of being a simple wide cæcum, has become extended in length and contracted in diameter, at the same time dividing and subdividing, so as to form an arborescent excretory duct, whose ramifications extend through the entire glandular mass. In this manner, then, is formed the complex system of hepatic ducts, which we find in the liver of the higher Vertebrata, branching out from the main trunk. But the mode in which the ultimate ramifications of these are arranged, and their relations with the secreting cells, which make up the *parenchyma* of the gland, have not yet been fully elucidated. The following are the principal facts, that have been ascertained on the subject.

Fig. 114.

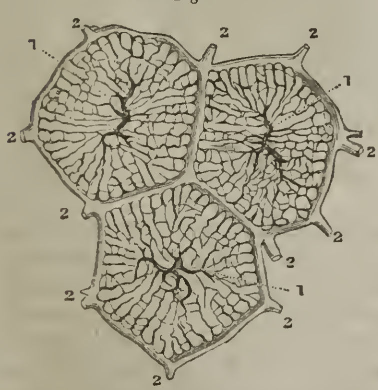


Liver of Tadpole; showing distinct and free cæcal terminations of the biliary ducts.

722. The entire Liver is made up of a vast number of minute *lobules*, of irregular form, but about the average size of a millet-seed. Each of these lobules contains the component elements, of which the

entire organ is made up;—namely, branches of the hepatic artery and vein, branches of the portal vein, branches of the hepatic ducts, and secreting cells. The lobules are connected together in part by areolar tissue, but in great part by the anastomosis of the blood-vessels and hepatic ducts, which supply the adjoining lobules; indeed there is frequently no definite division of the glandular substance into lobules, other than that, which is marked out by the arrangement of these canals (Figs. 115 and 117). The branches of the *Hepatic Artery* are principally distributed upon the walls of the hepatic ducts, and upon the trunks and branches of the portal and hepatic veins, supplying them with their *vasa vasorum;* also upon Glisson's capsule and its prolongations into the substance of the liver,—which prolongations form the greatest part of the connecting structure, that holds together the several elements. There is strong reason to believe, that the blood which the liver receives from the hepatic artery is not destined to supply the materials for the biliary secretion, until it has become venous by traveling through the network, in which it is subservient to the nutrition of the tissues it permeates, as it is in other parts of the systemic capillary system.—The supply of blood, from which the materials of the biliary secretion are chiefly drawn, is afforded by the *Vena Portæ*, which collects it as a Vein from the chylopoietic viscera, and which then subdivides as an Artery to distribute it to the different parts of the Liver. Its branches proceed to the capsules of the lobules, covering the whole *external* surface of the latter with their ramifications, and sending capillary twigs inwards, which converge towards the centre of each lobule (Fig. 115). As the prin-

Fig. 115.



Horizontal section of three superficial lobules, showing the two principal systems of blood-vessels; 1, 1, *intra*-lobular veins, proceeding from the Hepatic veins; 2, 2, *inter*-lobular plexus, formed by branches of the Portal veins.

Fig. 116.

Connection of the lobules of the Liver with the Hepatic vein; 1, trunk of the vein; 2, 2, lobules depending from its branches, like leaves on a tree; the centre of each being occupied by a venous twig—the Intralobular Vein.

cipal branches of these veins ramify in the spaces between the lobules, they are termed *inter*-lobular veins.—On the other hand, the branches

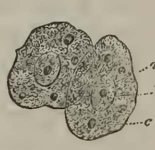
of the Hepatic Vein pass from the trunks to the centre of each lobule, from which they send out diverging capillary twigs towards the circumference; and these last, coming into connection with the converging capillaries of the portal vein, establish a free capillary communication between the interior and exterior of each lobule. Thus the portal blood is first distributed to its exterior, then penetrates its substance, and then, after permeating the parenchymatous substance in numerous minutely-divided streams, is collected and carried off by the hepatic vein, of which a twig originates in the centre of each lobule. Owing to the peculiar position of the branches of the hepatic vein in the centre of each lobule, the lobules are appended to its main trunks almost in the manner of leaves upon a stem (Fig. 116).—The precise relation of the capillaries of the hepatic artery with those of the portal and venous systems, has not yet been well ascertained; but there seems reason to believe, with Mr. Kiernan, that the arterial capillaries discharge themselves into the ultimate ramifications of the portal vein; and that thus the blood of the former, having become venous by transmission through the nutritive capillaries of the liver, mingles with the other venous blood collected by the venæ portæ, to supply the materials of the secretory function, which are eliminated from it during its passage into the hepatic vein.

723. The *Hepatic Ducts* also form a plexus, which surrounds the lobules; connecting them together, and sending branches towards the interior of each. The mode in which they terminate, however, and the precise relation in which they stand to the hepatic cells, which form nearly the entire parenchyma of the Gland, are yet unexplained.

Fig. 117.

Horizontal section of two superficial lobules, showing the interlobular plexus of biliary ducts; 1, 1, intralobular veins; 2, 2, trunks of biliary ducts, proceeding from the plexus which traverses the lobules; 3, interlobular tissue; 4, parenchyma of the lobules. (After Kiernan.)

Fig. 118.



Glandular cells of Liver:—*a*, nucleus; *b*, nucleolus; *c*, adipose particles.

These cells are of a flattened spheroidal form, and commonly lie in piles, their faces adhering to one another; and these piles seem to be directed especially from the circumference to the centre of each lobule. Every one of them presents a distinct nucleus; and the cavity of the cell is filled with yellow amorphous biliary matter, having one or two large adipose globules, or five or six small ones, intermingled with it.

Their diameter is usually from 1-1500th to 1-2000th of an inch; and they are easily obtained in a separate condition, by scraping a piece of fresh Liver. The biliary matter which they contain, marks them out as the real agents in the secreting process; this process consisting, it is evident, in the growth of the hepatic cells, which, in the course of their development, eliminate from the blood the biliary matter, for which they have a special affinity. The mode in which the particles thus eliminated, are discharged into the hepatic ducts, to be by them conveyed to the intestine, cannot be understood, until the relation between the secreting cells and the ultimate ramifications of the ducts shall have been more precisely determined.

724. The Bile which has been secreted by the hepatic cells, and which has found its way into the ramifications of the hepatic ducts, may be directly conveyed by the trunk of the latter into the intestine, or it may regurgitate along the cystic duct into the gall-bladder. It is probable that the secreting process is constantly going on; although, as in other cases, it may vary in its degree of activity at different times. When the process of digestion is taking place, and the small intestine is filled with chyme, there is probably an uninterrupted flow of bile into its cavity; but when the intestine is empty, the bile seems not to be admitted into it, but rather to flow back into the gall-bladder, in which it is stored up as in a reservoir, until the time when it may be needed. In this reservoir it undergoes a certain degree of concentration, by the absorption of its watery part; and it also becomes mixed with a large proportion of mucus, which is secreted by the walls of the gall-bladder. —As the analyses of Bile have been chiefly made upon the fluid obtained from this receptacle, they probably over-estimate the proportion of solid matter contained in this secretion; which is usually stated at from 8 to 9½ per cent. Of this solid matter about a tenth consists of alkaline and earthy salts, corresponding with those of the blood; whilst the remainder is made up of organic constituents. These are very readily decomposed, and enter into new combinations with the substances employed to separate them; so that different chemists, by employing different means of analysis, have obtained results which seem far from conformable. All are agreed, however, that the chief part of the solid ingredients of bile are allied to *fat* in composition; consisting of a very large proportion of carbon and hydrogen, and of a comparatively small amount of oxygen and azote. According to Dr. Kemp, the organic portion of ox-bile may be represented by the formula 48 Carbon, 42 Hydrogen, 13 Oxygen, and 1 Nitrogen. This substance, essentially corresponding with the bilic acid, choleic acid, bilin, picromel, &c., of different Chemists, seems to be a fatty acid, (§ 261), united with soda, so as to constitute a soap. In healthy bile, the proportion of Cholesterine appears to be very small; and it is held in solution by the preceding ingredient: but in many disordered states, and especially in disease of the Gall-bladder, this element is present in much larger amount; and it usually forms the principal, if not the sole, ingredient in biliary concretions. It is a white crystalizable

fatty matter, somewhat resembling spermaceti, free from taste and odour, and composed almost entirely of carbon and hydrogen,—its formula being 36 Carbon, 32 Hydrogen, and 1 Oxygen.—The Colouring matter of Bile is a substance distinct from the preceding; that of the Ox and other graminivorous animals appears to be identical, or nearly so, with the Chlorophyll of the leaves on which they feed; but that of human bile seems to possess different properties, and to be derived from the proper constituents of the blood.

725. Regarding the destination and purposes of this secretion in the Animal economy, the following may be considered as a tolerably complete summary; though it is difficult to speak with precision on some points; since the organic constituents of the Bile are liable to be so easily altered by various reagents, that they are with difficulty recognized. A portion of the Bile unquestionably passes off, in Man and most other animals, with the feces. This portion, which includes the colouring matter, is probably that which would be most injurious, if retained in the blood, and is most purely *excrementitious.* But the soapy portion has quite another destination. Just as ox-gall is commonly used to remove grease spots, by its solvent power for fatty matter, so does the bile seem to act in the living body, by rendering soluble the fatty matters of the food, and thus enabling them to be absorbed by the lacteals (§ 494). Hence, if the passage of bile into the intestine be prevented (as in the recent experiments of Schwann) without any check to its separation from the blood, the animals gradually lose their plumpness, and at last die in a state of emaciation,—the fatty matter of their food not being introduced into their absorbent system, nor applied to the maintenance of their respiration. The fatty matter of the bile, when re-absorbed with that of the newly-ingested food, is probably, like it, carried off by the respiratory process: but it is easily shown, that the biliary matter cannot supply more than one-sixth or one-eighth of the amount of carbon eliminated from the lungs in the form of carbonic acid; and that it cannot be (as supposed by Liebig) the chief fuel of the process of combustion, which is kept up through the agency of those organs.

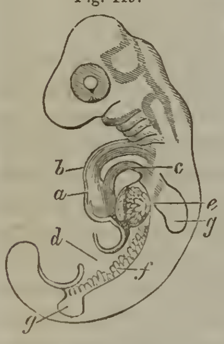
726. The elements of the Bile may be altogether supplied by the disintegration of the tissues; and this must certainly be the case, when the amount of food taken is no more than enough to supply the *waste* of the system. We may regard it, then, as one office of the Liver to remove from the blood such products of that disintegration, as are rich in carbon and hydrogen. But there can be little doubt, that the Liver has also for its office, to draw off from the blood any superfluity which may exist in the non-azotized compounds derived from the food, beyond the amount that is requisite for the supply of the respiratory process, or that can be deposited as fat. For we continually witness the results of habitual excess in the amount of such sbstances, in producing that state of the system commonly termed *bilious;* of which all the symptoms are referable to the accumulation of the elements of the bile from the blood, and the consequent deterioration in the purity of

the circulating fluid. Where a tendency to such a state exists, proper means should be taken to stimulate the liver to increased activity; but the chief reliance should be placed on the avoidance of those articles of diet, which contain a large proportion of non-azotized matter, and on abstinence from superfluous nutriment of any description. That the less hydro-carbon separated from the blood by Respiration, the more is eliminated from it by the Biliary secretion, seems to be a general principle throughout the Animal kingdom; the Liver and Respiratory organs bearing, almost everywhere, an inverse ratio to each other in their degree of development.

3. *Of the Kidneys and the Urinary Excretion.*

727. The Kidneys are perhaps the most purely *excreting* organs in the body; their function being to separate from the Blood certain matters that would be injurious to it if retained; and these matters being destined to immediate and complete removal from the system. We have seen that, in the Lungs, the excretion of Carbonic acid is made subservient to the absorption of Oxygen; and the separation of a fatty acid from the blood, which is effected by the Liver, is a means of introducing a new supply of fatty matter into the system. There is no ulterior purpose of this kind in the secreting action of the Kidney; the product of which is invariably conveyed directly to an outlet, by which it may be discharged from the body. Some traces of Urinary organs may be detected in most of the higher Invertebrata; but it is in Fishes, that they first present a considerable development; and in ascending through the Vertebrated series, we find them rapidly increasing in the complexity of their organization, and in their functional importance, although their size and extent are not so great. In Fishes the Kidneys very commonly extend the whole length of the abdomen; and they consist of tufts of uniform sized tubules, which shoot out transversely at intervals from the long ureter, and which are connected together by a loose web of areolar tissue, that supports the network of vessels distributed upon their walls. This condition of the urinary organs is very analogous to that of the Corpus Wolffianum or temporary kidney of the embryo of higher animals (Fig. 119, *f*). A similar condition is found in the true Kidney of higher animals at an early grade of development (as shown in Fig. 120); the tubuli uriniferi being short and straight. In their more advanced condition, however, they become long and convoluted; and the ramifications of the capillary vessels come into very close relation with them (Fig. 121). It is in the higher Reptiles, that we first meet

Fig. 119.



Embryo of Green Lizard:—*a*, heart; *b*, duplex aorta; *c*, vena cava; *d*, intestine; *e*, liver; *f*, rudiment of Wolffian body; *g*, *g*, rudiments of extremities.

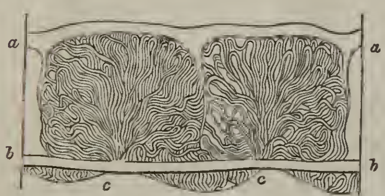
with the distinction between the *cortical* and *medullary* substance; the former being the part in which the blood-vessels are most copi-

Fig. 120.

Kidney of fœtal Boa:—the urinary tubes as yet short and straight.

ously distributed, and in which the tubuli have the most convoluted arrangement; and the latter consisting chiefly of straight tubuli, converging towards the points at which they discharge themselves into the ureter (Fig. 122). The bundles of tubuli and their vascular

Fig. 121.



Portion of Kidney from Coluber:—*a*, *a*, vascular trunk; *b*, *b*, ureter; *c*, *c*, converging fasciculi of tubuli uriniferi.

Fig. 122.

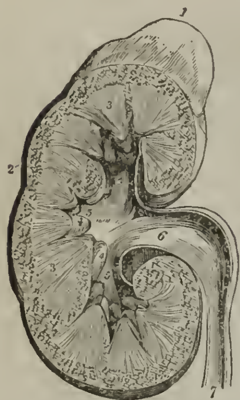
Pyramidal fasciculi of tubuli uriniferi of Bird, terminating in one of the branches of the ureter.

plexuses remain distinct, however, in Birds and in the lower Mammalia, so as to give to the gland a lobulated character; but in the Human Kidney, they come into closer contact; and the vascular connection between the plexuses of the different bundles is such, as to prevent any separation into distinct lobules.

728. The act of secretion appears to be effected, as in other Glands, by the epithelial cells lining the tubuli uriniferi; these cells drawing the materials of their development from the vascular plexus upon the exterior of these tubuli; and delivering them up, when they have completed their own term of existence, to be carried off through the open orifices of the tubuli. But the Kidney contains another apparatus, of a very peculiar description; which appears specially destined for the separation of the superfluous *fluid* of the system. When a section of the Kidney is slightly magnified (Fig. 124, B), the cut surface is seen to be studded by a number of little dark points; each one of which, when examined under a higher magnifying power, is found to consist of a knot of minute blood-vessels, formed by the convolutions of thin-walled capillaries (Fig. 125, *m*). According to the recent inquiries of Mr. Bowman, each one of these knots is included in the extremity of one of tubuli uriniferi, which swells into a flask-like capsular dilatation to receive it. Each of these vascular tufts (called

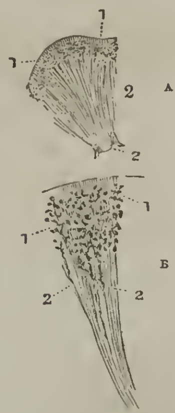
Malpighian bodies, after their discoverer), is directly supplied by a branch of the renal artery (Fig. 125, *af*); which, upon piercing the

Fig. 123.



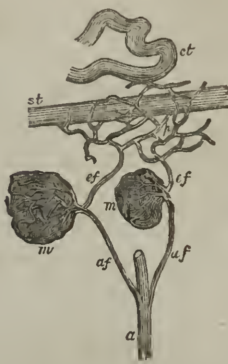
A section of the Kidney, surmounted by the supra-renal capsule; the swellings upon the surface mark the original constitution of the organ, as made up of distinct lobes. 1. The supra-renal capsule. 2. The vascular portion of the kidney. 3, 3. Its tubular portion, consisting of cones. 4, 4. Two of the papillæ projecting into their corresponding calices. 5, 5, 5. The three infundibula; the middle 5 is situated in the mouth of a calyx. 6. The pelvis. 7. The ureter.

Fig. 124.



Portion of the Kidney of a new-born infant. A, natural size; 1, 1. Corpora Malpighiana, as dispersed points in the cortical substance; 2, papilla. B, a smaller part magnified; 1, 1, Corpora Malpighiana; 2, 2, tubuli uriniferi.

Fig. 125.



Distribution of the Renal vessels; from Kidney of Horse:—*a*, branch of Renal artery; *af*, afferent vessel; *m*, *m*, Malpighian tufts; *ef*, *ef*, efferent vessels; *p*, vascular plexus surrounding the tubes; *st*, straight tube; *ct*, convoluted tube. Magnified about 30 diameters.

capsule, subdivides into a group of capillaries; and these, after forming the convoluted tuft, coalesce into a single efferent trunk (*ef*), which may be considered as representing (in a small way) the vena portæ. For the efferent trunks of the Malpighian bodies discharge their blood into the capillary plexus, which surrounds the tubuli uriniferi, and from which the solid matter of the urinary secretion is elaborated; just as the vena portæ supplies the capillary plexus, from which the biliary secretion is elaborated in the liver. The special purpose of the Malpighian bodies appears to be, to allow of the transudation of the *water* of the blood, which is filtered off (so to speak) through the thin walls of their capillaries, and thus passes into the tubuli uriniferi. It is well known that the fluid and solid constituents of the urinary secretion bear no constant relation to each other; the amount of fluid depending mainly upon the degree of fullness of the blood-vessels; whilst the amount of solid matter is governed, as we shall presently see, by the previous *waste* of the tissues. The quantity of fluid in the blood-vessels is governed by the relative amount that has been absorbed, and that which has been exhaled from the skin; so that the quantity to be drawn off by the Kidneys is increased, either by augmented absorption, or by diminished exhalation. The

Malpighian bodies seem to act the part of a system of regulating valves; permitting the transudation of only enough fluid to dissolve the solid matter, when there is no superfluity of water in the vessels; but allowing the escape of an almost unlimited amount of it, when increased imbibition has rendered the vessels unusually turgid.

729. The average amount of Urine excreted in twenty-four hours, by adults who do not drink more than the wants of nature require, is probably from 30 to 40 oz.; and its average specific gravity may be about 1020. The quantity of fluid is usually less, and the specific gravity of the secretion consequently greater in summer than in winter; on account of the larger proportion of fluid exhaled by the skin during the former season. The quantity of solid matter has been found to vary, within the limits of ordinary health, from 3·6 to 6·7 per cent.; and the extent of variation in disease is doubtless much greater. About one-third of the solid matter is made up of alkaline and earthy salts; and the remainder is made up of organic compounds. The salts are partly those of the blood, which will not be separated during the transudation of the serum through the membranous walls of the Malpighian capillaries, although the albuminous matter is kept back (§ 196). But there is a much larger proportion of the alkaline and earthy phosphates in the urine, than is present in the blood; and this is liable to a further increase under circumstances to be presently alluded to.

730. The organic compounds present in the Urinary secretion (in its healthy state at least), are undoubtedly the result of the *waste* or disintegration of the animal fabric; as well as (in certain cases) of the decomposition of constituents of the blood, which have never undergone conversion into organized tissue. Their unfitness to be retained within the system, is proved by the fatal results which speedily ensue, when their elimination by the secreting process receives a check; and also by the *crystaline* form, in which the most characteristic of them present themselves,—such a form being altogether incompatible with the possession of plastic or organizable properties. Of these compounds, the most important, in Man, is that which is named *Urea*. It exists in Urine in a state of perfect solution; and may be readily separated from it in the form of transparent colourless crystals, which have a faint and peculiar but not urinous odour. In its ultimate composition it is identical with Cyanate of Ammonia, being made up of 2 Carbon, 4 Hydrogen, 2 Nitrogen, and 2 Oxygen,—a formula much more simple than that of almost any other organic substance. If we compare its composition with that of Proteine, we shall find that it contains a far larger proportion of Nitrogen, and far less Carbon and Hydrogen. Thus, making Oxygen the standard of comparison, we find that

1 Equivalent of Proteine contains	40 C, 31 H, 5 N, 12 O.
6 Equivalents of Urea contain	12 C, 24 H, 12 N, 12 O.

731. Hence it seems evident, that the great purpose of the Urinary

excretion is to carry off those products of the metamorphosis of the azotized tissues, which can neither be set free in the condition of carbonic acid and water through the lungs, nor got rid of by the agency of the liver in the form of solid biliary matter. The amount of Urea in the Urine is liable to very great variation, in accordance with the degree in which the disintegrating process has been taking place in the solid fabric; and also in conformity with the amount of azotized matter, which has been taken in as food. Supposing that the latter were so precisely adjusted to the wants of the system, as to supply only that which is required for its maintenance, we might then measure the amount of previous *waste*, by the quantity of Urea present in the Urine. There can be no doubt as to the fact, that, other things being equal, the amount of Urea is greatly increased by any unusual exertion of the Muscular system; but such an increase cannot be invariably, or even usually, attributed to this cause; since it is equally certain, that any superfluity in the amount of azotized matter received into the blood, must be drawn off by the urinary excretion, and thus that an increase in the quantity of urea may be occasioned by an excessive use of proteine-compounds as articles of food. The average proportion of Urea, under ordinary circumstances as to diet and exercise, seems to be from 20 to 35 parts in 1000; but it may be raised to 45 parts by violent exercise, and to 53 parts by an exclusively animal diet; whilst it may fall as low as from 12 to 15 parts, when the diet is deficient in azotized matter. The total daily excretion of Urea in adult males seems to average about 430 grains, and that of females nearly 300 grains; but these averages may be widely departed from, on the side either of excess or diminution, according to the circumstances already noticed. It is interesting to observe, that children of eight years old excrete, on the average, *half* as much Urea as adults; whilst, in very old persons, the quantity sinks to *one-third*, or even less. In proportion to their relative bulks, therefore, children excrete at least two or three times the quantity of urea, that is set free by adults; and four or five times that which is excreted by old persons;—a fact which corresponds with other indications of the far greater rapidity of interstitial change in the earlier periods of life, than in adult or advanced age.

732. There is an organic compound, nearly allied to Urea in composition, but differing from it in its distinctly acid properties, and also in its comparative insolubility. This substance, termed *Uric* or *Lithic Acid*, forms but a small proportion of the solid matter of Human Urine in the state of health; but it is the chief element in the Urine of the lower Vertebrata; and its presence in too large a proportion is a frequent source of disease in Man. Its ultimate composition is 10 Carbon, 4 Hydrogen, 4 Nitrogen, 6 Oxygen; it crystalizes in fine scales of a brilliant white colour and silky lustre; and it is so sparingly soluble in water, that at least 10,000 times its own weight of fluid is required to dissolve it. In healthy Human urine, it is in a state of perfect solution; but it is precipitated immediately on the ad-

dition of a small quantity of any acid, even the Carbonic: it is evident, therefore, that it is held in solution by union with some base; and according to Liebig, this base is Soda, obtained from the bibasic Phosphate of Soda, which is present in the urine, and which, by yielding up a part of its base, gives the acid reaction that is characteristic of the fluid in a healthy state. It is not unfrequently seen, that the Urine, although clear when voided, deposits Lithic acid when it is cooled; and this deposit may be due either to the presence of more Lithic acid than the Phosphate of Soda can take up when cold; or to the presence of some other acids in the Urine, which set free the Lithic acid, when the solvent power of the Phosphate is diminished by the depressed temperature.

733. The amount of Uric acid in *healthy* Urine does not seem to be much influenced by the diet, or by the waste of the tissues; never varying much, either by excess or diminution, from 1 part in 1000. It is liable, however, to be greatly increased in certain disordered states of the system; and the surplus, not being kept in solution by the Phosphate of Soda, is deposited as a sediment, which usually has a crystaline character, and is tinged of a reddish hue by the colouring matter of the urine. Not unfrequently the Uric acid is deposited in combination with an alkaline base; and the colour of the sediment is then usually of a brick-red. Such depositions may take place directly from the blood; thus, in attacks of Gout, urate of soda is separated from the circulating blood, and is deposited in the tissues around the affected joints, forming the concretions termed "chalk-stones." There can be no doubt that, when there is a positive excess of Uric acid in the Urine, it may be generally reduced by diminishing the quantity of azotized matter in the food; but when the deposit is consequent upon the presence of some other acid in the urine, our treatment should be rather directed to the neutralization of this, or to the prevention of its formation.

734. There seems reason to believe that we are to regard *Hippuric* acid as a normal element of the Urine of Man, although it has been usually supposed to be restricted to the Herbivorous quadrupeds, where it replaces Uric Acid. Its composition and properties are very different from those of that substance. When pure, it forms long transparent four-sided prisms; it is soluble in 400 parts of cold water, and dissolves readily at a boiling heat; and it has a strong acid reaction, with a bitterish taste. It is composed of 18 Carbon, 8 Hydrogen, 1 Nitrogen, and 5 Oxygen, with 1 equiv. of Water. When exposed to a high temperature, or subjected to the putrefactive process, it is partly converted into Benzoic acid; and it is on the presence of the latter in putrefied Human Urine, that the belief in the existence of Hippuric acid in the same fluid when fresh, is chiefly grounded. It is a curious fact, that the administration of Benzoic acid causes the appearance of a large additional quantity of Hippuric acid in the Urine; so that its presence is then sufficiently evident. This fact has been applied to the treatment of disease; for as the salts of Hippuric

acid are much more soluble than those of Lithic acid, it is obviously advantageous to cause the effete crystaline matters, which are destined for elimination from the system, to be discharged as soluble Hippurates, rather than to be deposited as insoluble Lithates; and it is asserted by Mr. A. Ure, that he has succeeded, by the administration of Benzoic acid, in preventing the deposition of Gouty concretions, and even in removing them when they had been formed.

735. Another acid has usually been regarded, until recently, as one of the regular constituents of healthy urine, and as liable to undergo a considerable increase in disease. This is the *Lactic;* an acid which is readily formed in Milk, by the metamorphosis of its saccharine elements. But it seems doubtful, from the recent inquiries of Liebig, whether we are to admit it as a regular constituent of healthy human Urine; and it appears that a peculiar azotized compound, which is not entitled to the designation of an acid, but which forms a definite combination with Zinc, has been mistaken for it. The amount of this azotized product, and of the compounds it forms (usually designated as lactic acid and the lactates), has been found to undergo considerable increase, when the food ingested was altogether destitute of azote, and when the proportion of urea was the smallest. It would seem as if some of the azotized matter, resulting from the disintegration of the tissues, was then discharged in this form, rather than in that of the more highly azotized compound, urea.

736. Of the substances ranked under the head of *Extractive Matters*, very little is definitely known. They seem to consist, for the most part, of non-azotized compounds in a state of change; and their usual proportion, which is about 10 parts in 1000, has been found to increase to 16½ parts when the diet was exclusively vegetable, and to diminish to 5 parts when only animal food was ingested.

737. The Urine also contains a considerable amount of Saline matter, of which the acids as well as the bases are derived from the mineral kingdom; and the excretion of them, after they have served their purpose in the economy, appears to be one of the chief functions of the Kidney. Of these, a part may find their way directly into the urine from the serum of the blood, when its water is being filtered off (so to speak) through the walls of the Malpighian capillaries; for although, from the peculiar properties of animal membranes (§ 196), the albuminous constituents of the serum are held back, the saline matter, which is in a state of perfect solution, must pass with the water. This is probably the chief source of the large quantity of the muriates of soda and ammonia contained in the urine. But the Urinary secretion seems to be specially destined to eliminate the saline compounds, which are formed by the acidification of the Sulphur and Phosphorus, taken in with the proteine-compounds as food. These substances are united with Oxygen in the system, and are thus converted into Sulphuric and Phosphoric acids; which acids unite with alkaline bases, that were ingested in combination with Citric, Tartaric,

Oxalic, and other organic acids; the latter undergoing decomposition within the system, and leaving the bases ready to unite with others. Such weakly combined bases abound in the food of Herbivorous animals; and their urine is almost invariably *alkaline*, the quantity of the Sulphuric and Phosphoric acids generated in the system not being sufficient to neutralize it. On the other hand, they are nearly absent in the food of the Carnivora; and their urine is therefore almost invariably *acid*, from the want of neutralization of the Sulphuric and Phosphoric acids.

738. The Alkaline *Sulphates*, whether taken in as such, or formed in the manner now described, are soluble enough to be always passed off in a fluid form; but this is not uniformly the case with the *Phosphates*, which are frequently deposited as sediments of a dead-white aspect, sometimes crystaline, and sometimes wholly or partly amorphous. The crystaline sediment consists of the *triple phosphate*, or phosphate of ammonia and magnesia; the amorphous contains an admixture of the phosphate of lime. The urine, when these are deposited, is usually alkaline, sometimes very decidedly so; and there is reason to think that, in many cases, this alkaline character, and the deposit of phosphatic sediments, are due to an alkaline secretion from the walls of the bladder and urinary passages, which result from an irritable state of their membrane,—the urine, as secreted by the kidney, having its usual properties.* That an alkaline condition of the urine, resulting from the presence of an unusual amount of *bases*, is capable of producing a phosphatic deposit, is shown by the simple experiment of adding ammonia to healthy urine, which will occasion a precipitation of the triple phosphate.

739. But there can be little doubt, that a frequent cause of the deposit is excessive production of the phosphatic salts, arising from the increased waste or disintegration of Nervous matter, which takes place when it is in a state of unusual activity, either from intense thought, from prolonged exertion, or from continued anxiety. The general principles already set forth, in regard to the dependence of the functional activity of the Nervous Centres upon a supply of arterialized blood (§ 384), show the probability that every act of theirs involves the oxygenation of a certain quantity of nervous matter. In this oxygenation, phosphoric acid will be produced, from the large amount of phosphorus contained in the nervous matter; and this will unite in part with ammonia, which is perhaps set free by the same metamorphosis, or is derived from other sources; and in part with bases derived from the food. The experience of every studious man must have shown him (if he make any observations on the matter at all) the frequent coincidence between the presence of phosphatic deposits in his urine, and an excess of mental labour; and there are many instances on record, in which the periodical recurrence of the

* See Dr. G. O. Rees on the Analysis of the Blood and Urine in Health and Disease, 2d Ed. p. 136.

latter has been so invariably followed by the recurrence of the former, that no reasonable doubt can exist as to their mutual connection.

740. It is very important, for the successful treatment of those Urinary deposits, which consist of the normal elements of the Urine, —namely, Lithic Acid, and the Phosphates,—that the leading facts already stated should be borne continually in mind. In the first place, these sediments may depend upon the general condition of the fluid, and not upon any excess in the constituents of which *they* are composed; thus a lithic deposit may result from the presence of an excess of some other acid in the urine; and a phosphatic sediment may be produced by the excess of bases. In such cases, then, our treatment should be directed, not to diminish the quantity of the peculiar constituents of the deposits, but to rectify the state of the Urine on which their precipitation depends. But, in the second place, the sediments may be present in such great amount, as to indicate that their constituents are present in the urine to an excessive degree; and our treatment must then be directed towards the diminution of the quantity produced. Thus the tendency to lithic acid deposit may be frequently cured, by simply diminishing the quantity of azotized matter in the food; and the undue formation of the phosphates may be often kept in check by that mental repose, which is peculiarly required after long-continued and severe exercise of the intellectual faculties, or strong excitement of the feelings.

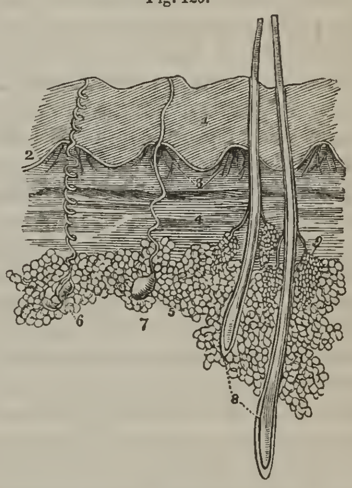
741. There is no doubt whatever, that the total suspension of the Urinary secretion is productive of rapidly fatal results, from the accumulation of the elements of the secretion in the blood; and it would appear that the tissue on which their presence in the circulating fluid exerts the most injurious effects, is the Nervous. It is probable that Urea is the substance, which is most directly concerned in producing the noxious influence; and we see an effort made by the system (so to speak) to get rid of it, in those cases in which a discharge of urinous fluid takes place by unusual channels, such as from the mucous membrane of the stomach, the mamma, the umbilicus, the nose, &c., when the usual secreting action of the Kidney has been suspended. Although the accounts of such cases have been treated with ridicule by some Physiologists, yet there seems no valid reason to discredit them, when it is borne in mind that, in persons who have died from the complete suspension of the secretion, effusions containing urea have been found in the serous cavities of the trunk, and in the ventricles of the brain. The poisonous influence of an accumulation of urea in the blood, when strongly exerted, produces, in the first instance, irregular or convulsive movements, which are dependent upon irritation of the Spinal system of nerves; then loss of consciousness, depending upon the suspension of the powers of the Brain; and, lastly, complete suspension of the powers of the spinal system, so that the ordinary reflex actions cease, and life becomes extinct from the stoppage of the respiratory movements (§ 688). There is reason to believe that many convulsive motions, for which no obvious cause can be assigned, have

their origin in a disordered condition of the blood, resulting from imperfect elimination of Urea; thus it has been ascertained that, in several cases of puerperal convulsions, urea was present in the blood; the functional power of the kidney being diminished by chronic disease. It is especially to be noticed, that most of the cases in which the urinary secretion is discharged through some irregular channel, occur in persons who have been subject to those convulsive affections, which are commonly designated as *hysterical;* and that the discharge of a large quantity of urine through the natural channel, is often the termination of an hysterical paroxysm. It is desirable, therefore, that in all such obscure cases, the state of the urinary secretion should be carefully looked to.

4. *Of the Cutaneous and Intestinal Glandulæ.*

742. The Glandulæ which are disposed in the substance of the Skin, and in the walls of the Intestinal canal, although individually minute, make up by their aggregation an excreting apparatus of no mean importance. The Skin is the seat of two processes in particular; one of which is destined to free the blood of a large quantity of fluid; and the other to draw off a considerable amount of solid matter. To effect these processes, we meet with two distinct classes of glandulæ in its substance; the Sudoriparous or sweat-glands; and the Sebaceous or oil-glands. They are both formed, however, upon the same simple plan; and can frequently be distinguished only by the nature of their secreted product.

Fig. 126.



The anatomy of the skin. 1. The epidermis, showing the oblique laminæ of which it is composed, and the imbricated disposition of the ridges upon its surface. 2. The rete mucosum or deep layer of the epidermis 3. Two of the quadrilateral papillary clumps, such as are seen in the palm of the hand or sole of the foot; they are composed of minute conical papillæ. 4. The deep layer of the cutis, the corium. 5. Adipose cells. 6. A sudoriparous gland with its spiral duct, such as is seen in the palm of the hand or sole of the foot. 7. Another sudoriparous gland with a straighter duct, such as are seen in the scalp. 8. Two hairs from the scalp, enclosed in their follicles; their relative depth in the skin is preserved. 9. A pair of sebaceous glands, opening by short ducts into the follicle of the hair.

743. The *Sudoriparous* or perspiratory glandulæ form small oval or globular masses, situated just beneath the cutis, in almost every part of the surface of the body. Each is formed by the convolution of a single tube; which thence runs towards the surface as the efferent duct, making numerous spiral turns in its passage through the skin, and penetrating the epidermis rather obliquely, so that its orifice is covered by a sort of little valve of scarf-skin, which is lifted

up as the fluid issues from it. The convoluted knot, of which the gland consists, is copiously supplied with blood-vessels. On the palm of the hand, the sole of the foot, and the extremities of the fingers, the apertures of the perspiratory ducts are visible to the naked eye, being situated at regular distances along the little ridges of sensory papillæ, and giving to the latter the appearance of being crossed by transverse lines. According to Mr. Erasmus Wilson, as many as 3528 of these glandulæ exist in a square inch of surface on the palm of the hand; and as every tube, when straightened out, is about a quarter of an inch in length, it follows that in a square inch of skin from the palm of the hand there exists a length of tube equal to 882 inches, or 73½ feet. The number of glandulæ in other parts of the skin is sometimes greater, but generally less than this; and according to Mr. Wilson, about 2800 inches may be taken as the average number of pores in each square inch throughout the body. Now the number of square inches of surface, in a man of ordinary stature, is about 2500; the number of pores, therefore, is *seven millions;* and the number of inches of perspiratory tubing would thus be 1,750,000; or 145,833 feet; or 48,611 yards; or nearly 28 miles.

744. From this extensive system of glandulæ, a secretion of watery fluid is continually taking place; and a considerable amount of solid matter also is drawn off by the epithelium-cells that line the tubuli. Under ordinary circumstances, the fluid is carried off in the state of vapour, forming the *insensible* perspiration; and it is only when its amount is considerably increased, or when the surrounding air is already so loaded with moisture as to be incapable of receiving more, that the fluid remains in the form of *sensible* perspiration upon the surface of the skin. It is difficult to estimate the proportion of solid matter contained in this secretion; partly on account of the great variations in the amount of fluid eliminated by the Sudoriparous glands, which are governed by the temperature of the skin; and partly because the secretion can scarcely be collected for analysis, free from the sebaceous and other matters which accumulate on the surface of the skin. According to Anselmino it varies from ½ to 1½ per cent.; and consists in part of lactic acid, to which the acid reaction and sour smell of the secretion are due; in part of a proteine-compound, which is probably furnished by the epithelium-cells that line the tubes; and in part of saline matters, directly proceeding from the serum of the blood.

745. The amount of fluid excreted from the skin is almost entirely dependent upon the *temperature* of the surrounding medium; being increased with its rise, and diminished with its fall. The *object* of this variation is very evident; being the regulation of the temperature of the body. When the surface is exposed to a high degree of external heat, the increased amount of fluid set free from the perspiratory glands becomes the means of keeping down its own temperature; for this fluid is then carried off in a state of vapour, as fast as it is set free; and in its change of form, it withdraws a large quantity of caloric

from the surface. But if the hot atmosphere be already loaded with vapour, this cooling power cannot be exerted; the temperature of the body is raised; and death supervenes, if the experiment be long continued. The *cause* of the increased secretion is probably to be looked for in the increased determination of blood to the skin, which takes place under the stimulus of heat.—The entire loss by Exhalation from the lungs and skin, during the twenty-four hours, seems to average a little above 2 lbs. In a warm dry atmosphere, however, it has been found to rise to as much as 5 lbs.; whilst in a cold damp one, it may be lowered to $1\frac{2}{3}$ lb. Of this quantity, the pulmonary exhalation is usually somewhat less than one-third, and the cutaneous somewhat more than two-thirds; but when the quantity of fluid lost is unusually great, the increase must be chiefly in the Cutaneous exhalation; since, as already pointed out (§ 701), the amount of exhalation from the lungs is not influenced by the external temperature, but only by the degree in which the surrounding air is previously saturated with moisture.

746. The variations in the amount of fluid set free by Cutaneous and Pulmonary Exhalation, are counterbalanced by the regulating action of the Kidney; which allows a larger proportion of water to be strained off in a liquid state from the blood-vessels, as the Exhalation is less,—and vice versâ. The Cutaneous and Urinary excretions seem to be vicarious, not merely in regard to the amount of fluid which they carry off from the blood; but also in respect to the solid matter which they eliminate from it. It appears that at least 100 grains of effete azotized matter are daily thrown off from the skin; and any cause which checks this excretion, must increase the labour of the Kidneys, or produce an accumulation of noxious matter in the blood. Hence attention to the functions of the skin, at all times a matter of great importance, is peculiarly required in the treatment of Urinary diseases; and it will be often found that no means is so useful in removing the lithic acid deposit, as copious ablution and friction of the skin, combined with exercise. When the Exhalant action of the skin is completely checked, by the application of an impermeable varnish, the effect is not (as might be anticipated) an elevation of the temperature of the body; on the contrary it is lowered, in consequence, as it would appear, of the interruption to the aëration of the blood through the skin, which is a function of such importance in the lower animals (§ 671), and of no trifling account in Man; and in a short time, a fatal result ensues. A partial suppression by the same means gives rise to febrile symptoms, and to Albuminuria, or escape of the albuminous part of the liquor sanguinis into the urinary tubes, in consequence (it would appear) of the increased determination which then takes place towards the kidneys. These facts are interesting, as throwing light upon the febrile disturbance, which accompanies those cutaneous diseases, that affect the whole surface of the skin at once, and interfere with its functions; and as accounting also for the Albu-

minuria, which frequently manifests itself during their progress, especially in Scarlatina.

747. The Skin is likewise furnished with numerous Sebaceous glands, which are distributed more or less closely over the whole surface of the body; being least abundant where the Perspiratory glandulæ are most numerous; and vice versâ. They are altogether absent on the palms of the hands and the soles of the feet; and are particularly frequent in the skin of the face, and in the scalp. They differ greatly in size and in degree of complexity; sometimes consisting of short straight follicles; sometimes closely resembling the Sudoriparous glandulæ, the tubes, however, being usually straighter and wider; and being sometimes much more complex in structure, consisting of a number of distinct sacculi clustered round the extremity of a common duct, into which they open, and forming little arborescent masses, about the size of millet seeds. In some situations they acquire still greater complexity. Thus the Meibomian glandulæ, which are found at the edge of the eyelids, and which secrete an unctuous matter for their lubrication, are long sacculi branching out at the sides (Fig. 107); and the glandulæ of the ear passage, which secrete its cerumen or waxy matter, and which belong to the general Sebaceous system, are formed of long tubes, highly contorted, and copiously supplied with blood-vessels. In the hairy parts of the skin, we usually find a pair of Sebaceous follicles opening into the passage through which every hair ascends (Fig. 126, 9). The purpose of the sebaceous secretion is evidently to prevent the skin from being dried and cracked by the influence of the sun and air. It is much more abundant in the races of mankind, which are formed to exist in warm climates, than in the races that naturally inhabit cold countries; and the former are accustomed to aid its preservative power, by lubricating their skin with vegetable oils of various kinds; which process they find to be of use in protecting it from the scorching influence of the solar rays.—The Sebaceous follicles are frequently the residence of a curious parasite, the *Demodex folliculorum;* which is stated by Mr. Erasmus Wilson to be present in great numbers in the skin of almost all inhabitants of large towns; the activity of their cutaneous glandular system being much checked, by the want of free exposure to pure air, and by inert habits of life.

748. To what extent the Sebaceous secretion can be regarded as destined to free the Blood from deleterious matters, it may not, perhaps, be very easy to say; but with regard to the functions of the skin taken altogether, as a channel for the elimination of morbific matters from the blood, it is probable that they have been much underrated; and that much more use might be made of it, in the treatment of diseases,—especially of such as depend upon the presence of some morbific matter in the circulating current,—than is commonly thought advisable. We see that Nature frequently uses it for this purpose; a copious perspiration being often the turning-point or crisis of febrile diseases, removing the cause of the malady from the blood, and

allowing the restorative powers free play. Again, certain forms of Rheumatism are characterized by copious acid perspirations; and instead of endeavouring to check these, we should rather encourage them as the best means of freeing the blood from its undue accumulation of lactic acid. And it is recorded that in the "sweating sickness," which spread throughout Europe in the 16th century, no remedies seemed of any avail but diaphoretics; which, aiding the powers of nature, concurred with them to purify the blood of its morbific matter. The hot-air bath, in some cases, and the wet sheet (which, as used by the Hydropathists, is one of the most powerful of all diaphoretics), will be probably employed more extensively as therapeutic agents, in proportion as the importance of acting on the skin, as an extensive collection of glandulæ, comes to be better understood. The absurdity of the "Hydropathic" treatment consists in its indiscriminate application to a great variety of diseases; no person, who has watched its operation, can deny that it is a remedy of a most powerful kind; and if its agency be fairly tested, there is strong reason to believe, that it will be found to be the most valuable curative means we possess for various specific diseases, which depend upon the presence of a definite "materies morbi" in the blood, especially Gout and chronic Rheumatism; as well as for that depressed state of the general system, which results from the "wear and tear" of the bodily and mental powers.

749. The Mucous surface of the Alimentary Canal is furnished, like the skin, with a vast number of glandulæ, varying in complexity, from the simple follicle, to a mass consisting of numerous lobules opening into a common excretory duct. The functions of these, as already pointed out, are equally various. The simple follicles appear destined, for the most part, to secrete the protective mucus, which intervenes between the membranous wall and the substances contained in the canal, and which serves to protect the former from the irritating action of the latter. The more complex follicles of the Stomach elaborate the Gastric fluid, which is the prime agent in the digestive process (§ 496). But there is strong reason to believe, that the function of the numerous glandulæ, which beset the walls of the small intestine, and which are known as Brunner's and Peyer's glands (after the names of their discoverers), is purely excretory; and that they are destined to eliminate putrescent matters from the blood, and to convey them, by the readiest channel, completely out of the body. That the putrescent elements of the feces are not immediately derived from the food taken in, so much as from the secreting action of the intestinal glandulæ, appears from this consideration;—that fecal matter is still discharged, even in considerable quantities, long after the intestinal tube has been completely emptied of its alimentary contents. We see this in the course of many diseases, when food is not taken for many days, during which time the bowels are completely emptied of their previous contents by repeated evacuations; and whatever then passes, must be derived from the intestinal walls

themselves. Sometimes a copious flux of putrescent matter continues to take place spontaneously; whilst it is often produced by the agency of purgative medicine. The "colliquative diarrhœa," which frequently comes on at the close of exhausting diseases, and which usually precedes death by starvation, appears to depend, not so much upon a disordered state of the intestinal glandulæ, as upon the general disintegration of the solids of the body, which calls them into extraordinary activity, for the purpose of separating the decomposing matter.

750. Thus we perceive, that we have here, also, to watch for the indications of Nature; and that this extensive system of intestinal glandulæ, being the principal channel for the elimination of putrescent matters from the blood, should be especially attended to, when there is reason to think that such matters are present in too large an amount. Hence, when diarrhœa is already existing, we may often do more good by allowing it to take its course, or even by increasing it by the agency of purgative medicines, than by attempting to check it, and thus causing the retention of the morbid matter in the circulating current. But, on the other hand, it is necessary to bear in mind the extreme irritability of the intestinal mucous membrane; and carefully to avoid exciting it, when it is already in excess, or when there is danger that it will supervene,—as in that form of Fever in which there is a peculiar liability to inflammation and ulceration of the walls of the alimentary canal.

5. *General Summary of the Excreting Processes.*

751. We have now passed in review the various processes, by which the products of the disintegration of the animal tissues are carried off; and we have seen that the necessity for their removal is much more urgent than for their replacement. A cold-blooded animal may subsist for some weeks, or even months, without a fresh supply of food; the waste of its tissues being so small, if it remain in a state of rest, as to be quite compatible with the continuance of its life; and a warm-blooded animal may live for many days or even weeks, provided that it has in its body a store of fat sufficient to keep up its heat by the combustive process. But in either case, if the exhalation of carbonic acid by the lungs, the elimination of biliary matter by the liver, the separation of urea or uric acid by the kidneys, or the withdrawal of putrescent matter by the intestinal glandulæ, be completely checked, a fatal result speedily ensues;—more speedily in warm-blooded animals than in those which cannot sustain a high independent temperature, on account of the greater proneness to decomposition in the bodies of the former, than in those of the latter;—and more speedily in the latter, when their bodies are kept at an elevated temperature by the warmth of the surrounding medium, than when the degree of heat is so low, that there is little proneness to spontaneous change in the substance of their bodies.

752. It may be taken as a general principle, in regard to the Excreting processes (including Respiration), that they have a threefold purpose ;—in the first place, to carry off the *normal* results of the waste or disintegration of the solid tissues, and of the decomposition of the fluids ; in the second place, to draw off the superfluous alimentary matter, which, though received into the circulating current, is not converted into solid tissue, in consequence of the want of demand for it ;—and in the third place, to carry off the *abnormal* products, which occasionally result from irregular or morbid changes in the system. Thus by the Lungs are excreted a large amount of carbon, and some hydrogen, resulting from the disintegration of the tissues, especially the nervous and muscular; the same elements in animals that take in a large proportion of farinaceous or oleaginous aliment, may be derived immediately from the food, without any previous conversion into solid tissue ; and there can be little doubt that the respiratory function is also an important means of purifying the blood from various deleterious matters, either introduced from without (such as narcotic poisons), or generated within the body (such as the poison of fever*). And it is important to bear this last circumstance in mind ; since it enables us to understand how, if *time* be given, the system *frees itself* from such noxious substances ; and points out the duty of the medical attendant to be rather that of supporting the powers of the body by judiciously devised means, and of aiding the elimination of the morbid matter through the lungs and skin by a copious supply of pure air, than of interfering more actively to promote that which Nature is already effecting in the most advantageous manner.

753. In like manner, the Liver is charged with the separation of hydrocarbon, in a fluid form ; for which a supply of oxygen is not requisite. This product is partly derived from the waste of the system ; but the arrangement of the biliary vessels leads to the belief, that much of it is at once derived from crude matter, taken up by the mesenteric veins, and eliminated from them by the hepatic cells, without ever passing into the general circulation. And various facts seem to indicate, that the Liver is also destined to remove from the blood extraneous substances, which are noxious to it. Thus, in cases where death has resulted from the prolonged introduction of the salts of Copper into the system, a considerable amount of that metal has been obtained from the substance of the gland.—It has been already pointed out (§ 720) that the Liver and Respiratory organs are developed in an inverse proportion to each other, in the different classes of animals ; the Liver being largest where the respiration is most feeble, and *vice versâ*. Now it is important to bear in mind, that the functional activity of the liver in any individual must be in like manner the greater, as the amount of respiration is less ; the hydro-

* There is strong reason to believe that, in many instances, a small amount of poisonous matter introduced from without, in the form of a contagion or miasm, may lead, by a process resembling fermentation, to the production of a large quantity of similar noxious substances in the animal fluids.

carbon, which is eliminated by the lungs, when *their* activity is the greatest, being thrown upon the liver for separation, when the respiration is feeble. We have seen that the amount of carbonic acid exhaled at high temperatures, is much less than that set free in a colder atmosphere; consequently, the liver is called upon to do more in warm climates, and is therefore peculiarly liable to disordered action,—unless the diet be carefully regulated, in accordance with the wants of the system.

754. The effects of diminished respiration, in producing an increase in the fatty constituents of the liver, are peculiarly well marked in the diseased condition produced in the geese, that are being prepared for celebrated Strasburg *patés*. The unfortunate bird is closely confined at a high temperature; so that the respiration is reduced to its minimum amount by the combined effects of warmth and muscular inaction; and it is then crammed with maize, which contains a large amount of oily matter. The consequence is, that its liver soon enlarges, and becomes unusually fatty; its cells being gorged with oil-globules, instead of each containing no more than one or two: and it is then ready for the epicureans who set so high a value on the *paté de foie gras*. A similar diseased condition of the liver frequently presents itself in Man, as a consequence of chronic disorders of the respiratory organs, which diminish the amount of hydrocarbon eliminated through their agency; this "fatty liver" is peculiarly common in the advanced stages of Phthisis.

Fig. 127.

Hepatic Cells gorged with Fat:—*a*, atrophied nucleus; *b*, adipose globules.

755. With regard to the Kidneys, it has been already pointed out that they are the special emunctories of the *azotized* products of the decomposition of the tissues; and that they serve also to convey away the overplus of such earthy and alkaline salts, as are readily soluble. Moreover, it has been shown that the surplus proteine-compounds, which are not required for the nutrition of the system, must be excreted by their agency, after having been metamorphosed into urea. And we have now to notice, that other matters of an injurious character, whether introduced from without, or generated within the system, are drawn off by the same channel. Thus the saline compounds, taken up by the absorbent process (§ 493), are for the most part set free through these organs; especially when their properties are such, as to excite the action of the kidneys in a peculiar degree. Thus, Prussiate of Potash has been detected in the urine, within two minutes after it had been introduced into the stomach. It has been sometimes noticed that Iodide of Potassium, when administered as a medicine, is retained within the body for some days, producing extensive cutaneous eruptions, or some other unusual consequence; and that it then suddenly begins to pass off by the kidneys, and is excreted in very large quantities. The effect of the inhalation of the vapour of turpentine, even in a very diluted state, in speedily imparting to the urine the odour of violets, is an evidence that not

merely the actual substances imbibed, but new and peculiar compounds to which they give rise, are thus eliminated by the Kidneys.

756. The most singular variations in the excretory function of the Kidneys are seen, however, when the Urine is charged with substances which are not only foreign to it, but are altogether foreign to the healthy body. The most remarkable instance of this is seen in the disease termed Diabetes, in which a large quantity of Sugar is formed, either directly from the food, or by the disintegration of the solid tissues; and in which this compound is eliminated by the Kidneys, imparting to the urine a saccharine taste. And another example of the same general fact is seen in the "oxalic diathesis," in which an unusual arrangement of the elements, that usually form urea or uric acid, gives rise to a new and peculiar compound, oxalate of ammonia; this being drawn off by the kidneys, and being decomposed by the calcareous matter present in the urine, gives rise to a deposit of oxalate of lime. In the treatment of such diseases, our attention must be given, not so much to the secreting organ, as to the condition of the system at large, of which the character of the secreted product is the indication or exponent.

757. To what has already been stated in regard to the exhalant functions of the Lungs and Skin, it may be added that many states of disease are marked by an unusual odour emitted from the body; and there can be little doubt that the peculiar odorous matter is preformed in the blood,—as we know that the ordinary scent of any species (whether Man, Dog, Horse, Goat, &c.,) may be set free from the blood of that species, by the addition of sulphuric acid. The existence of such odours, therefore, is not to be attributed to disordered function in the excreting organs; but to the formation of morbid products in the interior of the body, which these organs do their best to remove. The fetid breath, which frequently accompanies an attack of indigestion, is another instance of the power of the lungs to eliminate not merely Carbonic acid, but other products of the changes in composition, which the food undergoes when introduced into the system.

758. The same remarks apply, and with yet greater force, to the intestinal glandulæ; whose function it is, not merely to remove the putrescent matter ordinarily formed by the disintegration of the tissues, or by the decomposition of unassimilated food, but also to draw off the still more offensive products of such changes as take place in disease. Thus there are conditions of the system, in which, without any well-marked disorder, the feces emit a peculiarly fetid odour; and with these is almost always associated a depressed state of mind. Now it can scarcely be doubted, that the real fault is here rather in the early part of the nutritive operations, than in the excretory function; and that the fetor of the contents of the intestine depends upon the undue formation of putrescent matter in the system, which, by tainting the blood, causes its action upon the brain to become unhealthy. The object of the physician will be here to eliminate the

morbid product, by the moderate use of purgatives; and so to regulate the diet and regimen, as to correct the tendency to its formation. —An excessive fetor in the evacuations, as well as in the exhalations from the skin and lungs, is peculiarly characteristic of those very severe forms of typhus (now, happily, of comparatively rare occurrence), which are termed *putrid fevers*. Here the whole of the solids and fluids of the body appear to have an unusual tendency to decomposition, in consequence of the introduction of some morbid agent, which acts as a *ferment;* and the system attempts to free itself from the products of that decomposition, by the various organs of excretion, particularly the Skin and intestinal surface.

759. It is of great importance that the Student should form clear conceptions on this subject; and that he should not (as too often happens), by directing his remedies to the mere symptoms or results of a disease, act in precise opposition to the natural tendency of the system to free itself from some unusual noxious matter, through those channels which are ordinarily destined to carry off only the regular products of its disintegration.

CHAPTER X.

OF THE DEVELOPMENT OF HEAT, LIGHT, AND ELECTRICITY IN THE ANIMAL BODY.

760. It has been shown, in an earlier part of this volume (Chap. II.), that *all* Vital actions require a certain amount of *Heat* for their performance; and that there is a great variety amongst the different classes of Animals, both in regard to the degree of Heat which is most favourable to the several processes of their economy, and in regard to their own power of sustaining it, independently of oscillations in the temperature of the surrounding medium. As a general rule, the Invertebrated animals are *cold-blooded;* that is, they have little or no power of sustaining an independent temperature. The degree of energy of their vital actions entirely depends, therefore, upon the warmth they receive from the air or water they inhabit; they have no power of resisting the depressing influence of cold; and they are generally so organized, as to pass into a state of complete inaction or torpidity, when the temperature sinks below a certain point,—after gradually becoming more and more inert with every diminution in the heat of their bodies. The same is true, also, of most Fishes and Reptiles: but the animals of the former class, from the more equable temperature of the medium they inhabit, are not so liable to be reduced to inaction as the latter; being usually so organized, as to retain their activity so long as the water around them continues liquid; and

being actually imbedded in a frozen state, when the water around them is converted into ice, without the loss of their vitality. There are certain Fishes, however,—such as the Tunny, Sword-fish, and other large species of the Mackarel tribe,—which are able to sustain a temperature considerably above that of the sea they inhabit; thus in the Bonito, the heat of the body has been found to be 99°, when the temperature of the surrounding sea was but 80½°. It is not probable, however, that the temperature of the body would be kept up to the same standard, if that of the sea should be considerably lowered; but it would probably remain at from 18° to 20° above the latter. And in like manner, it has been noticed that many of the more active Reptiles possess the power of sustaining the temperature of their bodies at 10° or 15° above that of the surrounding air.

761. The classes of animals, which are especially endowed with the power of producing and maintaining heat, are Insects, Birds, and Mammalia. The remarkable variations which present themselves in the temperature of the first of these classes, and the connection of these variations with the condition of the animals, in regard to activity or repose, have already been sufficiently noticed (§ 123).—The temperature of Birds is higher than that of any other class of animals; varying from 100° to 111° or 112°. The lowest degree is found in some of the aquatic species, as the Gull, and in those which principally live on the ground, as the Fowl tribe; and the highest in the birds of most active flight, as the Swallow. The temperature of the Mammalia seems to range from about 96° to 104°; that of Man has been observed as low as 96½°, and as high as 102°. The variations are dependent in part upon the temperature of the external air; but are influenced also by the general condition of the body, as to repose or activity, the period of the day, the time that has elapsed since a meal, &c. A somewhat larger amount of caloric is generated during the day, than in the night; and the body is usually warmer, by a degree or two, at noon, than at midnight. There is also a slight increase during the digestion of a meal; and exercise is a powerful means of raising the temperature.—The range of temperature is much greater in disease; thus the thermometer has been seen to rise to 106° in Scarlatina and Typhus, and to 110¾° in Tetanus; whilst it has fallen to 82° in Spasmodic Asthma, and to 77° in Cyanosis and Asiatic Cholera.

762. In searching for the conditions, on which this production of heat within the Animal body is dependent, it is very important to bear in mind, that a similar generation of Caloric may be observed in the Vegetable kingdom. It appears from the most recent and exact experiments, that all *living* Plants are somewhat warmer than similar *dead* plants exposed to the same atmosphere; and that the elevation is the greatest in the leaves and young stems, in which the most active vital changes are taking place. But the most decided production of heat occurs in the *flowering* of certain Plants, such as the Arum, which have large fleshy receptacles, on which a great

number of blossoms are crowded; thus a thermometer placed in the centre of five spadixes of the *Arum cordifolium* has been seen to rise to 111°; and one placed in the midst of twelve spadixes has risen to 121°; whilst the temperature of the surrounding air was only 66°. In the *germination* of seeds, also, a great elevation of temperature occurs; which is rendered most evident by bringing together a number of seeds, as in the process of *malting*, so that the caloric is not dissipated as fast as it is generated; the thermometer, placed in the midst of a mass of seeds in active germination, has been seen to rise to 110°.

763. Thus it is evident that the chemical changes, which are involved in the operations of Nutrition, are capable of setting free a large amount of heat; which, although ordinarily dissipated from the vegetating surface too speedily to manifest itself, becomes sensible enough, when this rapid loss is checked. If we further examine into the nature of the chemical changes, which appear most concerned in this elevation of temperature, we find that they uniformly consist in the combination of the carbon of the plant with the oxygen of the atmosphere; so that a large quantity of carbonic acid is formed and set free, precisely in the manner of the Respiration of Animals. This process is so slowly performed, in the ordinary growth of Plants, that it is concealed (as it were) by the converse change,—the *fixation* of carbon from the carbonic acid of the atmosphere, under the influence of light (§ 83). But it takes place with extraordinary energy during flowering and germination; a large quantity of carbon being set free, by union with the oxygen of the air; and the starchy matter of the receptacle, or of the seed, being converted into sugar. Now it has been ascertained by careful experiments, that the amount of heat generated is in close relation with the amount of carbonic acid set free; and that, if the formation of the latter be prevented, by placing the flower or the seed in nitrogen or hydrogen, no elevation of temperature takes place; whilst if the process be stimulated by pure oxygen, so that a larger proportion of carbonic acid is evolved, the elevation of temperature is more rapid and considerable than usual.

764. Upon examining into the conditions under which Caloric is generated in the Animal body, we find them essentially the same. Wherever the temperature of the body is maintained at a regular standard, so as to be independent of variations in the warmth of the surrounding medium, we find a provision for exposing the blood most freely to the influence of oxygen, and for extricating its carbonic acid; thus in Birds and Mammals, the blood is distributed, in a minute capillary network, on the walls of the pulmonary air-cells, the gaseous contents of which are continually renewed; and in Insects, the air is carried into every part of the body, by the ramifying tracheæ. We constantly find a proportion between the amount of heat evolved, and that of carbonic acid generated; this is peculiarly evident in Insects, whose respiration and calorification vary so remarkably (§ 123); but it is also proved by comparing the amount of carbonic acid generated

by warm-blooded animals, when the external temperature is low, and when more heat must be evolved to keep the temperature of their bodies up to its proper standard, with that generated by the same animals in a warmer atmosphere, when the proper animal heat is diminished in amount (§ 691).

765. The sources of the Carbonic Acid thrown off by the lungs, have been already pointed out (Chap. VIII.): it is partly derived from the metamorphosis of the tissues; but partly, in all but purely carnivorous animals, more directly from the non-azotized portion of the food. The precise mode in which the carbon of this is united with the oxygen derived from the atmosphere, is not yet known; but it is certain that, in whatever manner the combination takes place, a certain measure of caloric *must* be generated. It appears, however, from various experiments, that the whole quantity of caloric generated by an animal in a given time, is *greater* than that which would be evolved by the combustion of the carbon, included in the carbonic acid evolved during the same time. Hence it is evident that *other* chemical processes occurring within the body are concerned in the maintenance of the temperature; and it is not difficult to point to some of these. It is probable, in the first place, that some of the hydrogen of the food may be "burned off" by union with the oxygen of the atmosphere, so as to form part of the water which is exhaled from the lungs. Again, the sulphur and phosphorus of the food are converted, by oxygenation, into sulphuric and phosphoric acids; in which process, heat must be generated. In the composition of urea, moreover, oxygen is present in much larger proportion, than it is in the proteine-compounds by the metamorphosis of which it is formed; so that in *its* production, too, caloric will be generated. In fact it may be stated as a general truth, that the whole excess of the oxygen absorbed over that which is contained in the carbonic acid exhaled (§ 690), must be applied to purposes in the laboratory of the system, in which caloric will be disengaged. Still, the amount of carbonic acid exhaled must always be the measure of the chemical processes, by which heat is generated in the body; because it is itself the result of the chief of these processes (the union of carbon and oxygen), and because the surplus amount of oxygen which is absorbed, and which is applied to other purposes, entirely depends upon it.

766. The power of maintaining a high independent temperature is usually much less in *young* warm-blooded animals, than in adults. There are considerable variations in this respect, however, amongst different species; for where the young animal is born in such an advanced condition, as to be thenceforth almost independent of parental assistance, it is capable of maintaining its own temperature; but where it is born in such a state as to require to be supplied with food by the parent for some time, it is also more or less dependent upon the warmth imparted to it from the parental body. This is peculiarly the case with the young of the Human species, which is

longer dependent upon parental aid, than that of any other animal. In the case of children born very prematurely, the careful sustenance of their heat is one of the points most to be attended to in rearing them; and even the most vigorous infants, born at the full time, are far from being able to keep up their proper standard without assistance, if exposed to a cool atmosphere. It has been ascertained that, during the first month of infant life, the mortality in winter is nearly double that of summer,—being 1·39 in January to 0·78 in July; and this striking difference cannot be attributed to any other cause, than the injurious influence of external cold, which the calorifying powers of the infant do not enable it to resist. As age advances, the power of generating heat increases, and the body becomes much more independent of external vicissitudes; so that, in adult life, the winter mortality is to that of summer, only as 1·05 to 0·91, or less than one-sixth more. In advanced age, the calorifying power again diminishes; and this we should anticipate, from the general torpor of the nutritive operations in old persons. Between 50 and 65 years of age, the relative winter and summer mortality are nearly as in the first month of infancy; and at 90 years, the average mortality of winter is much more than twice that of summer, being as 1·58 to 64.

767. It appears that there is not merely a difference in calorifying power at different ages, but at different seasons; the amount of heat generated in summer not being sufficient, in many animals, to prevent the body from being cooled down by prolonged exposure to a temperature, which is natural to them in winter. To what extent this is the case with Man, it is difficult to say. His constitution is distinguished by its power of adapting itself to circumstances; and he can live under extremes of temperature more wide than those, which most other animals can endure (§ 113). Whether in the torrid zone, or in the arctic regions, he can maintain his healthy condition under favourable circumstances; in each case his natural appetite leading him to the use of that kind and amount of food, which are best suited to the wants of his system. But the longer he has been habituated to a very warm or a very cold climate, the more difficult he at first finds it to live comfortably in one of an opposite character; as his constitution, having become adapted to one particular set of circumstances, requires *time* to accommodate itself to an opposite one.

768. The means by which the heat of the body is prevented from rising *above* its normal standard, even in the midst of a very high temperature in the surrounding air, are of the most simple character. The excreting action of the skin is directly stimulated by the application of warmth to the surface; and the fluid which is poured forth, being immediately vaporized, converts a large quantity of sensible caloric into latent, and thus keeps down the temperature of the skin. By this provision, the body may be exposed with impunity to *dry* air of 600° or more, so long as the supply of fluid be maintained. But it cannot long sustain exposure to air saturated with vapour, even

though it may not be many degrees hotter than the body; because the cooling act of evaporation from the skin cannot then be carried on.

769. The evolution of *Light* is a very interesting phenomenon, chiefly witnessed among the lower Animals, and usually supposed not to occur in any class above Fishes. It is particularly remarkable among the Radiata and inferior Mollusca. A large proportion of the *Acalephæ*, or Jelly-fish tribe possess the property of luminousness in a greater or less degree; and it is to small animals of this class, which sometimes multiply to an amazing extent, that the beautiful phenomenon of *phosphorescence of the sea* is chiefly due. In the midst of the soft diffused light thus occasioned, brilliant stars, ribbons, and globes of fire are frequently seen; these appearances being due to the luminosity of the larger species of the same tribe, or to that of other marine animals.—Some of the most remarkable examples of luminosity, in regard to the brilliancy of the light emitted, occur in the class of Insects. Here the emission is confined to one portion of the body, or to two or more isolated spots, instead of being diffused over a larger surface; and it is proportionably increased in intensity.

770. The phenomenon of Animal Luminousness appears usually attributable to the formation of a peculiar secretion; which, in many instances, continues to shine after removal from the Animal, so long as it is exposed to the influence of oxygen: and it seems not unreasonable to believe, that it depends upon a slow process of combustion, analogous to that which takes place when phosphorus is exposed to the air. There is a special provision, in Insects, for conveying a large supply of air through the peculiar substance, which is deposited beneath the luminous spots; and the power which Glow-worms, Fire-flies, &c., possess, of suddenly extinguishing their light, and as suddenly renewing it, seems to depend upon their control over the air-aperture or spiracle by which air is admitted,—the stoppage of the supply of air causing the immediate cessation of the luminousness, and its re-admission occasioning a renewal of the process on which it depends.—It is probable, however, that in certain cases, the luminosity is rather of an electrical character. There are several of the smaller Annelida or marine Worms, which are brilliantly luminous when irritated; the luminosity having the character, however, of a succession of sparks, rather than of a steady glow. It appears from the recent experiments of M. Quatrefages, that this peculiar luminosity is the especial attribute of the muscular system; and that it is produced with every act of muscular contraction in these animals.

771. Although no such luminosity is commonly manifested in any of the higher vertebrata, or in Man, yet there are well-authenticated cases, in which the phenomenon has presented itself in the *living* subject,*—luminous emanations from dead animal matter being of no unfrequent occurrence. In most of these cases, however, the indi-

* See an account of several cases of the Evolution of Light in the Living Human Subject, by Sir Henry Marsh, M. D., M. R. I. A., &c.

viduals exhibiting the luminosity had suffered from consumption, or some other wasting disease, and were near the close of their lives at the time; so that it is probable that a decomposition of the tissues was actually in progress, analogous to that which, when it occurs after death, imparts luminosity to the decaying body. One instance is recorded in which a large cancerous sore of the breast emitted light enough, to enable the hands on a watch-dial to be distinctly seen when it was held within a few inches of the ulcer; here, too, decomposition was obviously going on, and the phosphorescent matter produced by it was exposed to the oxygenating action of the atmosphere.

771. Slight manifestations of free *Electricity*, or, in other words, disturbances of Electric equilibrium, are very frequent in living animals; and they are readily accounted for, when we bear in mind that nearly all chemical changes are attended with some alteration in the electric state of the bodies concerned; and when we consider the number and variety of such changes in the living animal body. When slight, however, they can only be detected by refined means of observation; and it is only when they are considerable, that they attract notice. The most remarkable examples of the evolution of free Electricity in Animals, are to be found in certain species of the class of Fishes; the best known of which are the *Torpedo* or Electric Ray, and the *Gymnotus* or Electric Eel. These possess organs, in which Electricity may be generated and accumulated in large quantities, and from which it may be discharged at will. The shock of a large and vigorous Gymnotus is sufficiently powerful to kill small animals, and to paralyze large ones, such as men and horses: that of the Torpedo is less severe, but it is sufficient to benumb the hand that touches it.

772. The electric organs of the Torpedo (which, from being found on European shores, has been the most studied) are of flattened shape, and occupy the front and sides of the body; forming two large masses, which extend backwards and outwards from each side of the head. They are composed of two layers of membrane separated by a considerable space; and this space is divided by vertical partitions into hexagonal cells like those of a honeycomb, the ends of which are directed towards the two surfaces of the body. These cells, which are filled with a whitish soft pulp, somewhat resembling the substance of the brain, but containing more water, are again subdivided horizontally by membranous partitions; and all these partitions are profusely supplied with blood-vessels and nerves.—The electrical organs of the Gymnotus are essentially the same in structure; but they differ in shape, in accordance with the conformation of the animal.—In these, and the other Electrical fishes, the electric organs are supplied with nerves of very great size, larger than any others in the same animals, and larger than any nerves in other animals of similar bulk. These nerves arise from the top of the spinal cord, and seem analogous to the pneumogastrics of other animals.

773. The following conditions appear to be essential to the mani-

festation of the Electric powers of these animals. Two parts of the body must be touched at the same time; and these two must be in different electrical states. The most energetic discharge is procured from the Torpedo, by touching its back and belly simultaneously; the electricity of the back being positive, and that of the belly negative. When two parts of the same surface, at an equal distance from the electric organ are touched, no effect is produced, as they are equally charged with the same electricity; but if one point be further from it than the other, a discharge occurs, the intensity of which is proportioned to the difference in the distance of the points from the electric organ. However much a Torpedo is irritated, no discharge can take place through a single point; but the fish makes an effort to bring the border of the other surface in contact with the offending body, through which a shock is then transmitted. This, indeed, is probably the usual way in which the discharge is effected.—The identity of *animal* with *common* Electricity is proved, not merely by the similarity of the effects upon the feelings produced by the shock of both ; but also by the fact that a spark may be obtained, and chemical decompositions effected by the former, precisely as by the latter.

774. The voluntary power of the animal over its Electric organs, is dependent upon their connection with the nervous centres. If all the nerve-trunks supplying the organ on one side, be divided, the animal's control over that organ will be destroyed ; but the power of the other may remain uninjured. If the nerves be partially divided on either or both sides, the power is retained by the portions of the organs, which are still connected with the brain by the trunks that remain. Even slices of the organ, entirely separated from the body except by a nervous fibre, may exhibit electrical properties. Discharges may be produced, by irritating the part of the nervous centres from which the trunks proceed, so long as the latter are entire ; or by irritating the portions of the divided trunks, which remain in connection with the electric organs ; or even by irritating portions of the electric organs themselves, when separated from the nervous centres.—In all these respects, there is a strong analogy between the action of the nerves on the Electric organs, and their action on the Muscles. And as the latter contract by their own inherent powers, when stimulated by nervous influence, so does there seem reason to believe, that the evolution of Electricity takes place from some peculiar changes in the electric organs, of which changes the agency of the nerves is one of the conditions. To the idea that the nervous centres *produce* the electricity, that the nervous trunks convey it, and that the electric organs serve merely to store it up, there are several objections, and especially these ;—that there is nothing whatever in the structure of the brains of the Electrical Fishes, that marks them out as essentially different from those of the species to which they are otherwise allied ;—that the power of the nerve-trunk, in conveying the requisite stimulus to the electric organs, is destroyed as completely by *tying*, as by *dividing* the trunk, which would not be the case if the nervous

agency were itself of the nature of ordinary electricity (§ 396);—and that electric manifestations may be procured from the electric organs, by stimuli applied to themselves, after the complete severance of their connection with the brain,—just as muscles may be thrown into contraction by direct stimulation, under the same circumstances (§ 348).

775. It is another interesting point of analogy between the action of Muscles, and that of the Electrical organs, that the former (as is now fully proved by the elaborate and exact researches of Matteuci), is attended with electrical disturbance. In any fresh vigorous muscle, in a state of passive or tonic contraction, there is a continual electric current from the interior to the exterior, sufficient to excite the leg of a frog to energetic contraction, when its nerve is so applied to the muscle, as to receive the influence of this current. And a much more powerful current is produced, when the muscle is thrown, by a stimulus applied to its own nerve, into a state of energetic contraction. The explanation of the constant direction of the current, from the interior towards the exterior of the muscle, seems to be, that the changes connected with the nutrition and disintegration of the muscular tissue go on more energetically in its interior, than they do nearer its surface, where the proper muscular fibres are mingled with a large proportion of areolar and tendinous substance.

776. It has also been shown that there exists in the Frog, during its whole life, a continual current of Electricity, passing from its extremities towards its head. The conditions on which this current depends do not seem very evident; and as it has been detected in no other animal, it has been termed the *courant propre*, or peculiar current, of the Frog. It bears this curious analogy to the electric discharges of Fishes; that it is *not* manifested, if the connection be made between corresponding points of the opposite sides; but that it shows itself, when the communication is made between points higher or lower in the body, whether on the same or on opposite sides.

777. Manifestations of Electricity may be produced, in most animals having a soft fur, by rubbing the surface, especially in dry weather; this is a fact sufficiently well known in regard to the domestic Cat. Some individuals of the Human race exhibit spontaneous manifestations of electricity, which are occasionally of very remarkable power. There are persons, for instance, who scarcely ever pull off articles of dress, which have been worn next their skin, without sparks and a crackling noise being produced, especially in dry weather. This is partly due, however, to the friction of these materials with the surface, and with each other. But the case of a lady has been recently put on record, who was for many months in an electric state so different from that of surrounding bodies, that, whenever she was but slightly insulated by a carpet or other feebly-conducting medium, sparks passed between her person and any object which she approached. When she was most favourably circumstanced, four sparks per minute would pass between her finger and the brass ball of a stove at a dis-

tance of 1½ inch. Various experiments were tried, with the view of ascertaining if the Electricity was produced by the friction of articles of dress; but no change in these seemed to modify its intensity. From the pain which accompanied the passage of the sparks, this condition was a source of much discomfort to the subject of it.

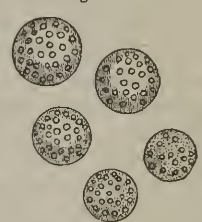
CHAPTER XI.

OF REPRODUCTION.

1. *General View of the Nature of the Process.*

778. THERE is no one of the functions of living beings, that distinguishes them in a more striking and evident manner from the inert bodies which surround them, than the process of Reproduction. By this function, each *race* of Plants and Animals is perpetuated; whilst the individuals composing it successively disappear from the surface of the earth, by that death and decay which are the common lot of all. There are certain tribes, in which the death of the parent is necessary for the liberation of the germs, from which a new race is to spring up. This is the case, for example, in some of the simplest Cellular Plants; in which every cell lives for itself alone, and performs its whole series of vital operations independently of the rest; and in which the process of reproduction consists in the rupture of the parent-cell, and the emission of the contained reproductive particles, every one of which is capable of developing itself into a new cell, resembling that of its parent and capable of going through the same series of changes (§ 31). But as, in more complex organisms, we find certain cells set apart for Absorption, others for Secretion, &c., so do we find a particular group of cells set apart for Reproduction; and these go through a series of changes analogous to those just described, yet without interfering with the general life of the structure.

Fig. 128.



Simple isolated cells containing reproductive molecules.

779. Among many of the lower Animals, a multiplication of individuals takes place by a process that closely resembles the *budding* of Plants; this must be regarded, however, not as a proper act of Reproduction, but as a modification of the ordinary Nutritive process. The same may be said of the powers of reparation, which every Animal body possesses in a greater or less degree, but which are by far the most remarkable among the lower tribes; for when an entire member is renewed (as in the Star-fish), or even the whole body is regenerated

from a small fragment (which is the case in many Polypes), it is by a process exactly analogous to that which is concerned in the reparation of the simplest wound in our own bodies, and which, as already explained (§ 636), is but a modification of the process that is constantly renewing, more or less rapidly, every portion of their fabric. The essential character of the special function of Reproduction, consists in the entire *separation* of certain germs from the parent structure; which are capable, by their own inherent powers, of developing themselves into new individuals: the only conditions requisite, being a proper supply of nutriment, and a certain amount of warmth. In the case of the simple Cellular Plants just now adverted to, the germs, when set free from the parent-cell, are thrown at once upon their own resources, and draw from the surrounding elements the materials of their growth and development (§ 32). But in the higher Plants, we find not only a set of germ-preparing organs, or reproductive cells (the pollen-grains), but also a set of germ-nourishing organs (the ovules); into which the reproductive granules are received, and in which they are supplied with nutriment previously elaborated by the parent, that serves to nourish them during the early stages of their development.

780. This is the universal method in which the Reproductive process is effected in Animals; the concurrence of two sets of organs being always necessary,—the germ-preparing organs, or *seminal cells;* and the germ-nourishing organs, or *ova*. These may be united in the same individual, as they are in most plants; and the ova may be fertilized from the seminal cells of the same being;—as happens in some of the lowest tribes of Mollusca. Or, the two sets of organs being present in each individual, it may not be capable of self-impregnation; but, in the congress of two individuals, each impregnates, and is impregnated by the other;—as may be observed in the Snail, and many of the higher Mollusks. Or the sexes may be altogether distinct; one individual possessing only the *male* or germ-preparing organs; and the other the *female*, or germ-nourishing apparatus.

781. The early Development of Animals may be so much better understood, when the general history of that of Plants is comprehended, that it is desirable here to give an outline of the latter subject.—Where, as in the simplest Cellular Plants, each individual consists, even in its adult state, but of a single cell, the development of one of the reproductive granules into the complete cell constitutes the whole history of its growth. In other cases, however, we have an extension of the original structure by a process of budding; so that, from the first-formed cell, a cluster, or filament, may be produced, according to the mode in which this budding takes place. Thus it may occur, as in *Palmella*, very much in the manner of ordinary Cartilage-cells, (§ 267, Fig. 37,) so as to produce a cluster of 2, 4, 8 or more; or it may proceed in a linear direction, as in Cartilage-cells near the ossifying surface, (Fig. 48,) so that a filament is the result, as the ordinary *Confervæ*. Now if the cells of one of the sim-

ple Confervæ, which is composed of single rows, bud out laterally, as well as longitudinally, a leaf-like expansion is formed, like that of the Sea-weeds. This simple organ has the power of performing the functions of absorption, digestion, respiration, &c., as well as that of reproduction ; and as it differs from the leaves of the higher plants (to which it otherwise bears a close resemblance), in its power of performing the last-named function, it is distinguished by the name of *frond.*

782. Although, in the highest Cryptogamia, the character of the Plant is ultimately to become very different from this, its formation commences in precisely the same manner ; so that the young Fern, which is afterwards to send a woody stem and beautifully-formed leaves into the air, and to transmit its solid roots deep into the ground, might be readily mistaken for an humble Liverwort, whose frond is not destined to raise itself from the ground, but creeps along its surface, and obtains its nourishment by the slight fibres which insinuate themselves into the soil. In both cases, the primary frond is evolved, in a precisely similar manner, by the budding of the original cell; but the Liverwort remains upon the lower grade, beyond which it is never destined to pass,—the primary frond being, in that class, the permanent plant ; whilst in the Fern, the primary frond is a temporary organ merely, the purpose of which is to obtain and elaborate the nutriment, that is destined for the evolution of the permanent structure. It is from the *centre* of this leafy expansion, that the true stem and roots of the Fern are subsequently put forth ; and the whole of the primary frond decays away, as soon as the first true leaf has unfolded itself.

783. Although the embryo of the Flowering Plant is developed under different conditions,—that is, at the expense of the nutriment provided for it in the seed, within which it is contained,—yet the history of its growth is essentially the same. The mass of cells, which originates from the pollen-granules that fertilize the ovule, does not at first take the form which the young plant is afterwards to present ; but spreads itself out into a single or double *cotyledon*, which is a leaf-like expansion, closely resembling the primary frond of the Fern. It is by this organ, that the nourishment provided in the ovule is absorbed and prepared for the development of the young plant ; the permanent fabric of which, even when the seed is mature, forms but a very small proportion of it. The development of the permanent structure takes place rapidly, however, during the process of germination; in which all the nourishment contained in the seed is prepared for the embryo by the cotyledons ; these serving the purpose of leaves, until the stem and roots have been developed, and the true leaves unfolded. By the time that this store has been exhausted, the development of the embryo has advanced sufficiently far, to enable it to support itself ; and the cotyledons then decay away.

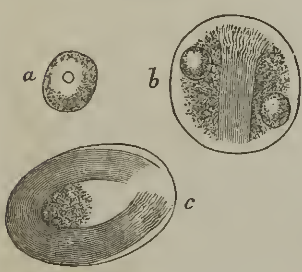
784. Thus we see that even the highest Plants have to pass through the conditions, which are permanently shown in the lower ; and that

the parts which are first formed, are destined for a temporary purpose only. We shall find, in tracing the history of the development of Animals, that exactly the same general fact may be observed, in even a higher degree;—the number of different stages being greater; and an even larger proportion of the parts first formed, in the embryo of the higher tribes, having a merely temporary purpose, and being destined to an early decay, as soon as the more permanent portions of the fabric have been evolved.

2. *Action of the Male.*

785. The share in the Reproductive function, which belongs to the Male Sex, essentially consists in the formation and liberation of the reproductive particles. These are prepared within peculiar cells, as already described (§ 240); and the cells are either scattered through the soft parenchyma of the body, as happens among some of the lowest animals; or they are confined to certain parts of it, as in those a little more elevated in the scale; or they are formed within follicles or tubes, clustered together into an organ of a glandular character, known as the *Testis*. Such an organ is found in all Insects and Mollusca; as well as in Vertebrated Animals. In the first of these classes, it is formed on the general plan of their proper glands (§ 720); being usually composed of tubes, more or less elongated, and sometimes terminating in enlarged follicles. In the Mollusks, on the other hand, it is almost invariably composed of clusters of follicles. In either case, the seminal cells are developed within the tubes or follicles, as are the ordinary secreting cells of the Liver or Kidney within the tubes or follicles of those glands; and their contents are discharged by an excretory duct, which terminates in an organ that conveys them out of the body, either emitting them into the surrounding water (as happens with many Mollusca), or depositing them within the body of the female. It is curious that, in some of the lowest Fishes, we should return to one of the simplest conditions of this organ,—a mass of vesicles, without an excretory duct. In these cases, the secretion formed within the vesicles escapes, by their rupture, into the abdominal cavity; whence it passes out by openings that lead directly to the exterior.

Fig. 129.

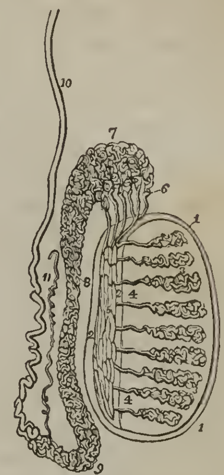


Formation of Spermatozoa within seminal cells:—*a*, the original nucleated cell; *b*, the same enlarged, with the formation of the Spermatozoa in progress; *c*, the Spermatozoa nearly complete, but still enclosed within the cell.

786. The *Testis* in Man is formed, in every essential particular, upon the plan of the ordinary Glands. It consists of several distinct lobules, separated by processes of the fibrous envelop, or tunica

albuginea, which pass down between them; and each lobule consists of a mass of convoluted tubuli seminiferi, through which blood-vessels are minutely distributed. The diameter of these tubuli is tolerably uniform; being, when they are not over-distended, from 1-195th to 1-170th of an inch. They form frequent anastomoses with each other; and on this account it is difficult to trace out their free or cæcal extremities. The tubuli of each testis discharge their contents into an efferent duct, the Vas-deferens; and by this the product is conveyed into the Vesicula seminalis on each side, which, like the gall-bladder and Urinary bladder, serves to store up the secretion until the proper time for discharging it. The product of the action of the Testis consists of a fluid, through which the Spermatozoa are diffused,—these last bodies being usually set free by the rupture of the seminal cells before they leave the tubuli of the testis. It is difficult to determine the precise characters of the fluid portion of the secretion; as this is mingled with other secretions (such as that of the Prostate gland, and of the mucous lining of the Vesiculæ seminales and spermatic ducts) before it is emitted. And an exact analysis is not of much consequence; since there can be no doubt that the peculiar powers of the fluid depend upon the Spermatozoa. It may be stated, however, that the Spermatic fluid has an alkaline reaction, and that it contains albumen, together with a peculiar animal principle termed Spermatine; and that it also includes saline matter, consisting chiefly of the muriates and phosphates, especially the latter, which form crystals when the fluid has stood for some little time.

Fig. 130.



Anatomy of the Testis:—1, 1. The tunica albuginea. 2, 2. The mediastinum testis. 3, 3. The lobuli testis. 4, 4. The vasa recta. 5. The rete testis. 6. The vasa efferentia, of which six only are represented in this diagram. 7. The coni vasculosi, constituting the globus major of the epididymis. 8. The body of the epididymis. 9. The globus minor of the epididymis. 10. The vas deferens. 11. The vasculum aberrans.

787. The minute filamentous bodies set free by the rupture of the spermatic cells, are distinguished by their power of spontaneous movement, which occasioned them to be long regarded as proper Animalcules. It is now clear, however, from the history of their development, as well as from other considerations, that they cannot be justly regarded in this light; and that they are analogous to the reproductive particles of Plants, which, in many cases, exhibit a spontaneous motion of extraordinary activity, after they have been set free from the parent structure. The human Spermatozoon consists of a little oval flattened body, from the 1-600th to the 1-800th of a line in length; from which proceeds a filiform tail gradually tapering to a very fine

point, of 1-50th or at most 1-40th of a line in length. The whole is perfectly transparent; and nothing that can be called structure can be satisfactorily distinguished within it. The movements are principally excited by the undulations of the tail; which give a propulsive action to the body. They may continue for many hours after the emission of the fluid; and they are not checked by its admixture with other secretions, such as the urine and the prostatic fluid. When the seminal fluid remains in contact with a living surface (as when deposited in the generative organs of the female) the Spermatozoa may retain their vitality for some days; and an instance has already been referred to (§ 240), in which the later stages of the development of the Spermatozoa actually take place in this situation,—the seminal fluid emitted by the male (among many Crustacea) not containing any Spermatozoa completely formed, but numerous spermatic cells, which undergo the remainder of their development, and then rupture and set free their contents, within the oviducts of the female.

788. The power of procreation does not exist in the Human Male (except in rare cases) until the age of from 14 to 16 years; at which epoch, the sexual organs undergo a much increased development; and the instinctive desire, which leads to the use of them, is awakened in the mind. From that time, to an advanced age, the procreative power remains, in the healthy state of the system; unless it be exhausted by excessive use of it, or by too energetic a direction of the mental or corporeal powers to some other object. The formation of Seminal fluid being, like the proper acts of Secretion, very much influenced by conditions of the nervous system, is increased by the continual direction of the mind towards objects which arouse the sexual propensity; and thus, if sexual intercourse be very frequent, a much larger quantity of the fluid will be produced, than if it is more rarely emitted, although the amount discharged on each occasion will be less. The formation of this product is evidently a great tax upon the corporeal powers; and it is a well-known fact, that the highest degree of bodily and mental vigour is inconsistent with more than a very moderate indulgence in sexual intercourse; whilst nothing is more certain to reduce the powers, both of body and mind, than excess in this respect.

789. It may be stated as a general law, prevailing equally in the Vegetable and Animal kingdoms,—that the development of the individual, and the reproduction of the species, stand in an inverse ratio to each other. We have seen that, in many organized beings, the death of the parent is necessary to the production of a new generation; and even in numerous species of Insects, it follows very speedily upon the sexual intercourse. It is a curious fact, that Insects which usually die, the male almost immediately after the act of copulation, and the female very soon after the deposition of the eggs, may be kept alive for many weeks or even months, by simply preventing their copulation. And there can be no doubt, that, in the Human race, early death is by no means an unfrequent result of the excessive or premature employment of the genital organs; and where this does

not produce an immediately fatal result, it lays the foundation of future debility, that contributes to produce any forms of disease to which there may be a constitutional predisposition, especially those of a Scrofulous nature.

790. The emission of the Spermatic fluid is an act of a purely *reflex* nature; the Will having no power either to effect or to restrain it. The stimulus is given by the friction of the surface of the Glans Penis against the rugous walls of the Vagina; the sensibility of the organ being at the same time much increased, by the determination of blood to it. The impression is at last sufficiently strong to produce, through the medium of the lower part of the Spinal cord, (which is the ganglionic centre of the circle of afferent and efferent nerves connected with this organ,) a reflex contraction of the muscles surrounding the vesiculæ seminales. These receptacles discharge their contents (which consist partly of the Spermatic fluid, and partly of a secretion of their own), into the Urethra; and from this they are expelled with some degree of force and with a kind of spasmodic action, by its own Compressor muscles. Although the sensations concerned in this act are ordinarily most acutely pleasurable, yet there appears to be sufficient evidence that they are by no means essential to its performance; and that the impression conveyed to the Spinal cord may excite the contraction of the Ejaculator muscles, like other *reflex* operations, without producing sensation (§ 394).

3. *Action of the Female.*

791. As it is the office of the Male to *prepare* the germ of the future being, and then to set it free, so is it the part of the Female to receive this germ, and to supply it with the materials for its development, up to the condition in which it can support its own life. The mode in which this is accomplished, is essentially the same with that, in which the process is effected in Plants. In certain parts of the female structure are developed peculiar bodies termed *ova;* which contain a store of nutriment, adapted to supply the wants of the germ. The reproductive particles find their way into these, and begin to grow at the expense of the materials which they meet with in their interior. This may enable the embryo to develop itself, without any further assistance (save a warm temperature), into the form it is permanently to assume; as in the case of Birds and Reptiles, which do not come forth from the investments of the egg, until they have attained the form characteristic of the group to which they belong. Or it may only serve for the early part of the process; and one of two methods may then be employed to complete it. Either a new connection is formed between the parent and embryo, by which the former continues to supply the latter with nutriment, more directly from its blood; as is the case with Mammalia—or the embryo issues from the egg, in a condition very unlike that which it is permanently to attain, but in a form which enables it to acquire its own nourish-

ment, and to pass through the latter stages of its evolution quite independently of any assistance from its parent; this is the case with a large proportion of the Invertebrata.

792. Sometimes the permanent form of the latter is elaborated, as it were, out of the temporary, by the gradual development of new parts; as happens in most of the Worm tribe,—the animal, at the time of its first emersion from the egg, possessing but a few segments, or even but a single one; but afterwards, by the progressive development of new segments, to the number in some instances of several hundreds, acquiring a great length. In other cases, there is a complete *metamorphosis* or change of form; the animal at its emersion from the egg, not merely having an aspect which is entirely different from that which it is ultimately to present, but possessing organs which it is afterwards to lose. Thus the Frog emerges in the state of a Fish; and in this, its Tadpole condition, it breathes by gills, swims by its tail, and has all the essential characters of the class below its own. Certain of its organs gradually disappear altogether, whilst others are as gradually developed; and in this manner the temporary Fish is converted into the permanent Reptile. The metamorphosis is even more striking in Insects; which come forth from the egg as Worms; and which attain their complete form by what appears to be a sudden change,—this change being really, however, of a very gradual character, the organs characteristic of the perfect Insect being slowly developed, during the preceding state of quiescence which usually characterizes the life of the Chrysalis, but being displayed and brought into use only when the Chrysalis-skin is thrown off. Thus the whole life of the Insect, up to this last change, may be regarded as one of embryonic development; and the same may be said of the condition of the Frog, up to the time when its permanent organs are fully evolved.

793. The Ova, like the seminal cells, are scattered through the soft parenchyma of the body, in animals of the lowest class; but they are more commonly developed in certain distinct portions of the fabric; being sometimes formed in the midst of solid masses of areolar or cellular texture; whilst in other instances they are developed, like the spermatic cells, in the interior of tubes and vesicles resembling those of glands, and furnished with an excretory duct. The latter condition obtains in the greater proportion of the higher Invertebrated animals, and in some Fishes; but in the Vertebrated classes we return to the type which characterizes the egg-producing organs in many Zoophytes,—namely, the development of the egg in the midst of a mass of solid parenchyma, from which it gradually makes its way, to escape into the abdominal cavity. The Ovarium of the Mammal, Bird or Reptile, as well as that of most Fishes, differs entirely, therefore, from that of the Invertebrata; for the latter have all the essential characters of true glands; whilst the former are nothing else than masses of parenchyma, copiously supplied with blood-vessels, and having dispersed through their substance certain peculiar cells, termed

ovisacs, within which the ova are developed. In order that the latter may be set free, not only must the ovisac itself burst (like parent-cells in general), but the peculiar tissue, and the envelops, of the ovarium must likewise give way. When the ova thus escape into the abdominal cavity, they may lie there for some time, at last to be discharged through simple openings in its walls, as happens in those Fishes which have this form of ovarium; or they may be at once received into the trumpet-shaped expansions of tubes, that shall convey them to these orifices. These tubes are termed *oviducts*, in common with the excretory ducts of the glandular ovaria of Invertebrated animals; for their function is the same,—that of conveying the ova to the outlet by which they are extruded from the body. They are represented in Mammalia by the Fallopian tubes, which are true oviducts; but these unite and enlarge to form a *Uterine* cavity, in which the embryo may be retained, whilst it is receiving the further assistance to its development, in the manner to be presently explained. This uterine cavity is peculiar to the Mammalia; but there are many cases among the lower classes, in which the ovum is retained within the oviduct, so that the young comes into the world alive; and a few in which, during this delay, it receives a direct supply of additional nourishment from the fluids of its parent.

794. The essential structure of the *ovule*, or unfertilized egg, appears to be the same in all animals. It consists externally of a membranous sac, termed, from the nature of its contents, the *yelk-bag*. The *yelk*, or contained fluid, consists chiefly of albumen and oil-globules; and it is this substance, which, like the starchy and oily matter laid up in the seed of the Plant, is destined to afford support to the embryo, until it is able to obtain its own nutriment, or, as in Mammalia, forms a new connection with the parent. Floating in this fluid is a cell of peculiar aspect, termed the *germinal vesicle;* and upon its wall is a very distinct nucleus, termed the *germinal spot.*—The layer of albumen surrounding the yelk, and termed the *white* of the Bird's egg, together with the membrane which envelops this and forms the basis of the shell, are not added until after the ovum has left the ovarium. They are not present in the eggs of many of the lower Invertebrata; these consisting merely of the parts which are formed within the ovarium.

795. The structure of the ovule in Mammals differs in no essential particular from that just described; but the yolk is much less in amount, than in the ovules of Invertebrated animals; since only the very earliest stages of the development of the embryo are to take place at its expense. We shall find that the ovule, after leaving the ovarium and receiving the fertilizing influence, becomes enclosed, whilst passing through the Fallopian tube, with a layer of albuminous matter, which represents the *white* of the Bird's egg; and with an additional fibrous envelop, which corresponds with the membrane enveloping the latter. This fibrous membrane, termed the Chorion, afterwards becomes subservient, however, to various important

changes; by means of which the ovum is again brought into connection with the parent, to derive from the blood of the latter the materials requisite for the continued development of the embryo. These changes will be described hereafter (§ 811).

796. The Ovisac of Mammalia forms the *inner* layer of what is termed the *Graafian follicle*, after the name of its discoverer; and instead of closely enveloping the ovulum, as it does in oviparous animals, it contains, in addition to it, a quantity of granular matter, consisting of cells arranged in membranous layers, together with fluid. Of these layers, one surrounds the ovulum, and is termed the *tunica granulosa;* another lines the ovisac, and is named the *membrana granulosa;* whilst, to certain bands passing from the former to the latter, and suspending the ovule (as it were) in the cavity of the ovisac, the name of *retinacula* has been given by their discoverer, Dr. Barry.—The *outer* layer of the Graafian follicle is formed by a thickening and condensation of the surrounding parenchyma of the ovarium; and it is quite distinct from the ovisac which it envelops. It is extremely vascular, and is evidently destined to afford to the structures within the materials for their development, which they receive and appropriate by their own powers of absorption and assimilation.

797. The Mammalian Ovarium may be seen, even in the fœtal animal, to contain immature ova, enclosed within their ovisacs; and the several parts of the former may be clearly distinguished, in those which are in the more advanced stages of development. It appears that, during the period of childhood, there is a continual rupture of the ovisacs (or parent-cells), and a discharge of ova, at the surface of the ovarium; but these ova never attain so high a degree of development, as to render them fit for impregnation. Their evolution takes place more completely, as well as more rapidly, at the period of puberty, when there is a greatly increased determination of blood to the genital organs, and a correspondingly augmented energy in their nutritive operations. At this epoch, the parenchyma of the ovarium is crowded with ovisacs; which are still so minute, that in the Ox, according to Dr. Barry's computation, a cubic inch would contain 200 millions of them. Some of those nearest the surface, however, are continually attaining increased development; and a rupture of some of the Graafian follicles, and a discharge of ova prepared for impregnation, from the exterior of the ovarium, thenceforth take place, with more or less tendency to *periodicity*, during the whole time that the female is in a state of aptitude for procreation.

798. In the Human female, the period of Puberty usually occurs between the 13th and 16th year. The differences in the time of its advent partly depend upon individual constitution, and partly upon various external circumstances, such as temperature, habits of life, &c. As a general rule, habitual exposure to a warm atmosphere, an inert life, sensual indulgence, and circumstances that excite the sexual feelings, favour the approach of Puberty; whilst a cold climate and

hardy life retard it. The appearance of the Catamenial discharge usually takes place whilst the evolution of the genital organs is in progress; and it is a decided indication, when it occurs, that the aptitude for procreation has been attained. It is not unfrequently delayed much longer, however; and its absence is by no means to be regarded as a proof of inability to conceive. The Catamenial secretion, which proceeds from the lining membrane of the Uterus, seems to consist of the elements of Blood, in an altered condition. It contains a considerable amount of red colouring matter; but the albuminous and fibrinous constituents seem to be present in smaller proportion than in Blood. The coagulating power is for the most part wanting, when the function is performed in a healthy manner; the appearance of clots being an indication that blood is escaping from the secreting surface. The coagulation of the fibrin normally present in the secretion, appears to be prevented by admixture with the vaginal mucus; but when an increased amount is poured forth, this admixture is not sufficient to destroy its power of forming a clot. In some cases of difficult Menstruation, which seem to depend upon a state of low inflammation in the Uterus, the fibrin has such a tendency to become organized, as to form shreds, or layers of false membrane, which sometimes plug up the os uteri. The healthy Menstrual secretion is remarkable for its very acid character.

799. This flux of altered blood from the lining membrane of the Uterus, is not confined to the Human female, as was formerly supposed; but occurs in most of the lower Mammalia in the state of *heat*, or periodical aptitude for procreation, at which time the ovarium contains ova ready for impregnation. The chief peculiarity attending its appearance in the Human female, is its regular monthly return. In the natural condition of many of the lower Mammalia, as in Oviparous animals, the period of heat recurs at some one time of the year,—usually in the spring; or, in the smaller and more prolific species, from two to six times. And in those which have undergone a change by domestication, the recurrence is usually irregular, depending upon various circumstances of regimen, temperature, &c. The general analogy between the Menstruation of the Human female and the heat of the lower Mammalia,—consisting in the peculiar aptitude for impregnation which then exists, in consequence of the maturation of ova in the ovarium,—cannot now be questioned; but it appears that, in the Human female, ova *may* be matured and impregnated at any part of the period, which elapses between the occurrences of the Catamenial discharge; though it is certain that the aptitude for conception is much greater, during the few days which precede and follow the menstrual period, than at any intervening time. The duration of the period of aptitude for procreation, which is marked by the continued appearance of the Catamenia, is more limited in Women than in Men; usually terminating at about the 45th year. It is sometimes prolonged, however, for ten or even fifteen years longer; but cases are rare, in which women above 50

years of age have borne children. There is usually no menstrual flow during pregnancy and lactation; in fact, the cessation of the Catamenia is usually one of the first signs indicating that conception has taken place. It is by no means uncommon, however, for them to appear once or twice subsequently to Conception; and their appearance during Lactation, especially if it be much prolonged, is still more frequent; hence it might be inferred, that the continuance of Lactation would not prevent a fresh conception,—which is found to be true in practice.

800. We shall now take a brief survey of the changes which occur in the Ovulum, when it is being prepared for fecundation; and of the principal features of its subsequent development.—Up to the period when the Ovule is nearly brought to maturity, it remains suspended in the centre of the cavity of the Ovisac; but it then begins to move towards that side of the Graafian follicle, which is nearest the surface of the ovarium. An important change is at the same time occurring in the Graafian follicle itself; for whilst the part with which the ovule comes in contact gradually thins away, the outer or vascular layer of the remainder, especially on that side most deeply imbedded in the ovary, becomes much increased in thickness; and a deposition of fibrinous matter seems to take place at that part, between this layer and the inner layer or proper ovisac. This fibrinous matter is destined subsequently to become more or less completely organized; receiving vessels, which are prolonged into it from its enveloping membrane: and it then forms the *corpus luteum*. The escape of the ovule from the ovarium involves processes which are essentially the same, whether it be impregnated or not; but the subsequent changes differ in the two cases, so that the corpus luteum which accompanies the pregnant state is a much more highly organized body than that which is found in the ovary of the unimpregnated female. This difference may be due in part to the absence, in the latter case, of that special determination of blood to the genital organs, which takes place in the former.

801. When the ovule is being thus brought near the surface of the Ovary, a series of remarkable changes takes place in its interior. The yelk becomes filled with cells; which, after passing through several generations (during which the transparency of the yelk is much interfered with), completely disappear, leaving the fluid apparently in the same condition as before. This process of cell-development in the substance of the yelk, continues for some time after fecundation; and it probably has for its purpose, to prepare the matter of the yelk for its subsequent functions; just as we have seen reason to believe, that the albuminous matter of the chyle is rendered fit for the nutrition of the body, by the development of floating cells in its current (§ 213). But the most curious changes are those, which take place within the germinal vesicle. Though previously in the centre of the yelk, it now moves up towards one side of it, and becomes flattened against the yelk-bag. At the same time, the

edge of its nucleus begins to resolve itself into a ring of cells; which sprout forth, as it were, from its inner wall, into its cavity. These cells enlarge; and another ring is developed nearer the centre of the nucleus, pushing the former one outwards. A third ring is next formed internally to the second; and a similar development of successive annuli of minute cells, one within another, continues, until the whole germinal vesicle is filled with minute cells; of which those constituting the outer and first formed rings are the largest, whilst those forming the central rings are very minute. The centre of what was the germinal spot remains transparent; and into this the germ finds its way in the act of fertilization, by the means to be presently described. All these cells, like those of the yelk, have a merely temporary existence, and speedily deliquesce again; and their function appears to be, to prepare the contents of the germinal vesicle for being applied to the nutrition of the germ, which is to be subsequently introduced into it.

802. By the changes in the position of the Ovulum and of its contained parts, which have been already noticed, the germinal vesicle is brought into very close proximity with the surface of the Ovary. It is still covered, however, by the peritoneal coat of the ovary; by a thin layer of the fibrous substance of that organ; by the ovisac; and by the yelk-bag, which, in the Mammalian ovum, is known as the *zona pellucida*. The three former of these envelops gradually thin away, and at last rupture, and give passage to the ovule; which thus escapes from the surface of the ovarium. At about the same time, a chink or fissure is formed in the part of the yelk-bag, that covers the central pellucid space of the germinal spot; and into this space the fertilizing influence appears to be introduced; for we find it afterwards occupied by two new cells, of very different appearance from the rest, from which the whole of the embryonic structure is subsequently to be developed.

803. Much discussion has taken place, with regard to the exact point at which the fertilization of the ovulum takes place; but this does not seem to be a matter of much consequence, as we find the order of the different steps to vary considerably in different classes of animals. Thus in many aquatic Mollusca, and even in a large proportion of the class of Fishes, there is no act of copulation whatever; but the spermatic fluid, when emitted by the male, is diffused through the water, and fertilizes the ova, which have been deposited by the female in his neighbourhood. In the Frog, again, and in other Reptiles, the spermatic fluid is emitted upon the ova, at the time that they are being extruded by the female. In many Insects and Crustacea,—in which a single congress often serves to fertilize many thousand eggs, the deposition of which occupies a period of several weeks or months,—the spermatic fluid is received and stored up in a saccular dilatation of the oviduct of the female, which is termed the *spermotheca;* and in this manner it serves to impregnate the ova, as they are successively developed, and are conveyed to the outlet of the oviduct.

In Birds, we find that ova are often set free from the ovarium in a state of full maturity, but without fertilization; and that they receive their additional layer of albumen and their shelly envelop, in passing down the oviduct, so as, at the time of their deposition, to differ in no obvious particular from fertile eggs. It is doubtful, in regard to Mammalia, whether the act of fertilization takes place before the ovum has been actually discharged from the ovisac, or subsequently to its finally quitting the ovarium and being received into the Fallopian tube. It is quite certain that the spermatozoa frequently, if not invariably, find their way to the surface of the ovary, being carried thither by their own spontaneous movements; and it seems on the whole most probable, that the fertilization of the ova usually takes place before they have been discharged from the ovisac, or whilst they are still in the commencement of the Fallopian tube. It is not unlikely that the place of the act of fecundation varies, according to the point at which the ovule and the seminal fluid first come into contact,—which may depend upon the degree of maturity of the ova at the period of copulation.

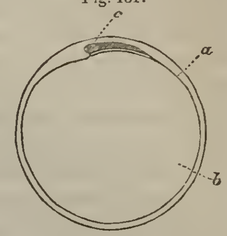
804. Everything indicates that the contact of the Spermatozoon with the Ovulum is the one thing needful in the act of fecundation; and there is strong reason to believe, that the large end of the Spermatozoon finds its way into the fissure just described, which is formed in the Zona pellucida; and that it there deposits the germs of the two new cells, which are afterwards seen within the germinal vesicle. We have seen that this is the essential nature of the fecundating process in the Flowering Plant; the reproductive granules, prepared within the pollen-cell, being conveyed by the pollen-tube within the ovule, where they speedily develop themselves into the first cells of the embryonic structure. The manner in which the reproductive germs of the Animal find their way to the ovary, is different, as we have seen; a power of spontaneous movement (which finds its resemblance in that of the sporules of the Confervæ, &c.) being imparted to them, by which they bring themselves into contact with the ovum.

805. From this stage, an entirely new set of changes begins to take place in the interior of the Ovum, during its passage along the Fallopian tube or oviduct. The two new cells, which at first occupy only the pellucid centre of the germinal spot, rapidly increase in size, and begin to develop new cells in their own interior. At the same time they press upon the cells, which filled the germinal vesicle previously to its fertilization; and these gradually liquefy or dissolve away, until all trace of them is lost; and the twin-cells, with their offspring, are alone contained within the germinal vesicle. Each of the first-formed cells gives birth, by the usual process of cell-development, to a new generation of two; so that the number is now four; from these four is produced a third generation of eight; and these go on progressively doubling, until at last a mass is produced, closely resembling a mulberry, in which the number of cells is too great to admit of being counted. This "mulberry mass" is obviously analogous to the col-

lection of cells, which is first developed within the seed of the Flowering Plant (§ 783); and between the condition of the Animal and that of the Vegetable embryo, at this period, there would not seem to be any essential difference.

806. In the next stage, however, a marked difference shows itself, which is very characteristic of the two kingdoms respectively. The mass of cells, which is the rudiment of the Vegetable embryo, spreads itself out into a flat leaf-like expansion,—the primary frond, or cotyledon,—which remains as the permanent form of the lowest plants, but is only temporary in the higher (§ 782). But in the embryo of the Animal, the "mulberry mass," having moved up to the side of the yelk, and having become flattened against its enveloping membrane, sends off from its edges a layer of cells, which passes round the yelk, so as completely to enclose it within a membranous envelop, the exterior of which is in contact with the yelk-bag. A second layer is afterwards formed within the preceding, from the central part of the mulberry mass; and, in the higher animals, a third is subsequently formed between them. This membranous formation, as a whole, is known as the *germinal membrane ;* its external pellicle is termed the *serous layer ;* the internal is termed the *mucous layer ;* and the intermediate one, which gives origin to the first vessels of the embryonic structure, is termed the *vascular layer.*

Fig. 131.



Plan of early uterine Ovum. Within the external ring, or zona pellucida, are the serous lamina, *a;* the yelk, *b;* and the incipient embryo, *c.*

807. Thus the first development of the Animal embryo is into a sac, enclosing the store of nutriment that has been prepared for it,—in fact, a stomach; and we shall presently see, that it is by the agency of the walls of this sac, that the nutrient materials which it encloses are prepared for being appropriated to the development of the more permanent part of the fabric, which is to be evolved from the centre of the mulberry mass. But we may here stop to notice the interesting fact, that the development of the ovum in the *lowest* classes of animals may be said almost to stop at this point; the external layer of the germinal membrane remaining as the integument; the internal layer becoming the lining of the stomach; and the space occupied by the yelk forming the digestive cavity, into which an entrance or *mouth* is formed, by the thinning-away of the germinal membrane at a certain point, round which *tentacula* or prolonged lips are usually developed. This is the essential part of the history of development in the simpler Polypes; and we see how remarkably it corresponds with the history of development of the lower Cryptogamic plants, in which the first-formed membranous expansion, or primary frond, remains as the permanent leaf.

808. In the higher Animals, on the other hand, the greater part of the germinal membrane, and of the cavity which it forms, have a

merely temporary purpose; being cast off, when they have performed their function, like the cotyledons of Flowering Plants. Nearly the whole of the permanent structure of the embryo is formed from a single large cell; which at first occupies the centre of the "mulberry mass;" but which is seen at the surface of the latter, when this undergoes the flattening already described. This cell, together with the cluster of ordinary cells that surrounds it, is that which forms the *cicatricula* or germ-spot upon the surface of the yelk-bag, in the impregnated ovum of the Fowl; and, whilst still retaining its clearness, it forms a large round transparent space in the centre of the cicatricula, which is known as the *Area pellucida*. The nucleus of this Embryonic cell, which was at first annular, changes its form into that of a pear, and then into that of a violin; and consists at last of two long parallel lines, enclosing a narrow space between them, but separating and enclosing a wider space at one extremity. In this state, it is called the Primitive Trace. The same process then takes place within the Embryonic cell, which has been described as occurring within the Germinal vesicle; the granules forming the outer border of the nucleus being first developed into cells; these being pushed outwards by a new series subsequently generated nearer the centre; and these being displaced, in their turn, by a continuance of the same process. It is from the peripheral cells originating in this primitive trace, that the inner layers of the germinal membrane (§ 806) seem to be developed; the cells that originate nearer its centre, are those from which the more permanent portions of the embryonic fabric are evolved. The principal steps of that process will be presently noticed; we must now stop to consider the changes which take place in the female generative apparatus, subsequently to the liberation of the ovum from the ovarium, but having relation to the new connection, which is to be afterwards formed between the embryo and its parent.

809. During the time which is occupied by these important changes, the Ovum passes through the Fallopian tubes, and makes its way into the Uterus. During its transit through the Fallopian tubes, the Mammalium ovum,—like the ovum of Birds in its passage through the oviduct,—receives an additional layer of albuminous matter secreted from the walls of the tube; and this is surrounded by a fibrous membrane, whose structure and mode of formation have been described on a former occasion (§ 181). The outer layer of this envelop, in the egg of the Bird, is further consolidated by the deposition of particles of carbonate of lime in its areolæ; but it undergoes no higher organization. In the Mammal, however, this new envelop (termed the *Chorion*) is a formation of great importance; being the medium through which the whole subsequent nutrition of the embryo is derived. This is at first taken in by means of a number of villous processes, proceeding from the entire surface of the Chorion, and giving it a spongy or shaggy appearance; these processes (which are composed of nucleated cells) serve as absorbing radicles, which draw in the fluids afforded by the parent; and they thus make up for the early exhaustion of the small

supply of nutritious matter stored up in the ovum itself. The contained embryo appropriates the fluid which is thus imbibed, by simple absorption through its surface; and thus it is nourished, until a more special provision for its development comes into action. The structure of this organ, termed the *Placenta*, cannot be understood, until the concurrent changes in the lining membrane of the Uterus have been considered.

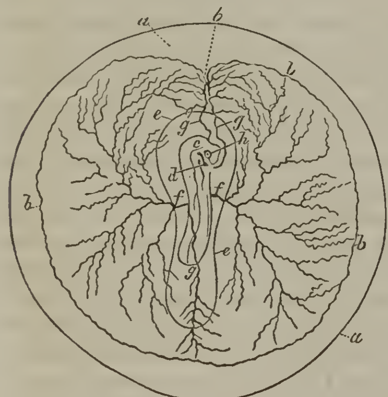
810. This membrane, in its natural condition, presents on its free surface the orifices of numerous cylindrical follicles; which are arranged parallel to each other, and at right angles to the surface. In the spaces between these follicles, the blood-vessels form a dense capillary network. When impregnation takes place, this mucous membrane swells and becomes lax; its capillaries increase in size; the follicles are turgid with a white epithelium; and the interfollicular spaces are crowded with nucleated cells, which fill up the meshes of the capillary network. In this peculiar condition, the uterine mucous membrane is termed the *Decidua*. At a later period, the decidua may be found to consist of two distinct layers; the *decidua vera*, lining the uterus; and the *decidua reflexa*, covering the exterior of the ovum. It was formerly supposed that the latter was a portion of the former, which had been pushed before the ovum at its entrance into the uterus; but the two layers are now known to be so different in texture, that they cannot be supposed to have the same origin; and there seems much probability in Mr. Goodsir's view, that the decidua vera is chiefly formed by the highly vascular mucous membrane itself, and the decidua reflexa by the abundant production of epithelial cells from its follicles.

811. When the ovum has arrived in the Uterus, therefore, and the villous tufts of its chorion are developed, these come into contact, in the first instance, with the layer of *cellular* decidua, which intervenes between them and the *vascular* decidua. Through this cellular membrane, therefore, the ovum must derive its nutriment from the vascular surface; and it cannot be deemed improbable, that the office of the cellular decidua is to draw from the subjacent vessels the materials which are to serve for the nutrition of the ovum, and to present it to the villous tufts of the chorion. Each of these, as already mentioned, is composed of an assemblage of nucleated cells, which are found in various stages of development; and these are always enclosed within a layer of basement-membrane, which seems itself to be composed of flattened cells united by their edges. At the free extremity of each villus, is a bulbous expansion, the cells composing which are arranged round a central spot; and it is at this point that the most active processes of growth take place, the villus elongating by the development of new cells from its germinal spot, and, like the spongiole of the plant, drawing in nutriment from the soil in which it is imbedded.—In its earliest grade of development, as already remarked, the chorion and its villi contain no vessels; and the fluid drawn in by the tufts is communicated to the embryo, by the absorbing powers of its germinal

membrane. But when the tufts are penetrated by blood-vessels, and their communication with the embryo becomes much more direct, the means by which they communicate with the parent are found to be essentially the same;—namely, a double layer of cells, one layer belonging to the fœtal tuft, the other to the vascular maternal surface. (See § 819.)

812. We now return to the Embryo itself; the general history of whose development has been already traced, up to the period at which the inner part of the elongated nucleus of the embryonic cell is beginning to give origin to the permanent structures of the fœtus. The parts first formed in the embryo of Vertebrated animals, are such as most characteristically distinguish them from all others;—namely, the Vertebral column, and Spinal Cord. The latter is formed in the groove, which runs along the median line of the primitive trace; and it is surrounded, when first developed, by a tubular structure, which has but a temporary existence in the higher Vertebrata, but which is permanent in the lower Fishes. This structure, termed the *Chorda dorsalis*, is found to be composed, wherever it exists, of nucleated cells. From the cells exterior to this, the vertebral column is developed; and this makes its first appearance in the condition of two rows of minute opaque plates, imbedded in ridges that rise up on either side of the central groove, and constituting the arches of the incipient vertebræ. These ridges incline towards each other; and at last meet and cover-in the groove, so as to complete the bony cylinder protecting the spinal cord. Towards the anterior extremity, however, they do not at once close in; and the large cells, in which the great divisions of the Encephalon originate, may be seen between them.

Fig. 132.



Vascular Area of Fowl's egg, at the beginning of the third day of incubation;—*a*, *a*, yelk; *b*, *b*, *b*, *b*, venous sinus bounding the area: *c*, aorta; *d*, punctum saliens, or incipient heart; *e*, *e*, area pellucida; *f*, *f*, arteries of the vascular area; *g*, *g*, veins; *h*, eye.

813. During the progress of this change, another very important one is taking place, which has reference to the nutrition of the embryo during its further development. This is the formation of *vessels* in the substance of the germinal membrane; which vessels serve to take up the nourishment supplied by the yelk, as well as that derived from the chorion externally, and to convey it through the tissues of the embryo. These vessels are first seen in that part of the vascular lamina of the germinal membrane, which immediately surrounds the embryo; and they form a network, bounded by a circular channel, which is known

under the name of the *Vascular Area* (Fig. 132). This gradually extends itself, until the vessels spread over the whole of the germinal membrane. The vessels are probably formed by the coalescence of the original cells of the layer; and the first blood-discs which they contain seem to originate in the nuclei of these cells. This network of vessels serves to receive the nutritious matter contained in the yelk-bag, and to convey it to the embryo; but the act of absorption seems to be performed here as elsewhere, by cells,—a layer of which always intervenes between the vascular layer and the yelk itself. These cells probably correspond in function with those of the villi of the intestinal canal in the adult (§ 242); as the vessels of the yelk-bag, or temporary digestive cavity, represent those of the alimentary canal, to be afterwards developed from a portion of it. The vessels of the yelk-bag terminate in two large trunks, which enter the embryo at the point that afterwards becomes the umbilicus, and which are known as the *Omphalo-Mesenteric*, *Meseraic*, or *Vitelline* vessels. The first movement of fluid takes place *towards* the embryo; and this may be witnessed before any distinct heart is evolved.

814. The formation of the Heart takes place in the substance of the Vascular layer; by a dilatation of the trunk, into which the blood-vessels unite. At first it appears as a mere excavation, surrounded by cells; but its walls gradually acquire firmness and consistency, and are endowed with a contractile power that enables them to execute regular pulsations. In this early condition, the heart is known as the *punctum saliens* (*d*, Fig. 132). The first appearance of the heart in the Chick is at about the 27th hour; the time of its formation in Mammalia has not been distinctly ascertained.

815. Concurrently with the formation of the Vascular system, the production of the permanent Digestive cavity commences. This originates in the separation of a small portion of the yelk-bag, lying immediately beneath the embryo, from the general cavity, in the following manner.—At about the 25th hour of incubation, in the Fowl's egg, the parts of the germinal membrane which lie beyond the extremities, and which spread out from the sides of the embryo, are doubled in, so as to make a depression upon the yelk; and their folded edges gradually approach one another under the abdominal surface of the embryo, so as at last to meet and enclose a cavity, which is at first simple in its form, but which is subsequently rendered more complex by the prolongation and involution of its walls in various parts, so as to form the stomach and intestinal tube (Figs. 133, 134, 135). This digestive cavity communicates for some time with the yelk-bag (from which it has been thus pinched off, as it were), by a wide opening, that is left by the imperfect meeting of the folds of the germinal membrane that constitute its walls. In the Mammalia, this orifice is gradually narrowed, and is at last completely closed; and the yelk-bag, thus separated, is afterwards thrown off. It may be detected, however, upon the umbilical cord, up to a late period of pregnancy, and is known as the *Umbilical vesicle*. In Birds, and other oviparous

animals, the whole of the yelk-bag is ultimately drawn into the abdomen of the embryo; the former gradually shrinking, as its contents are exhausted; and the latter enlarging, so as to receive it as a little pouch or appendage. In Fishes, the hatching of the egg very commonly takes place before the process has been completed; so that the little Fish swims about with the yelk-bag hanging from its body.

816. Whilst these processes are going on in the Vascular and Mucous layers of the Germinal membrane, a remarkable change is taking place in that portion of the Serous lamina, which surrounds the Area pellucida. This rises up on either side in two folds (Fig. 133); and

Fig. 133.

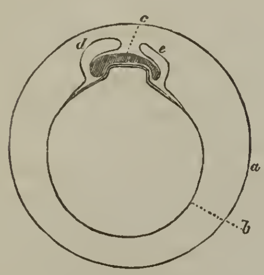
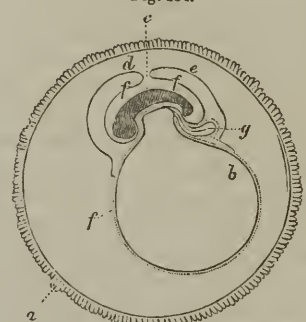


Diagram of ovum at later stage; the digestive cavity beginning to be separated from the yelk-sac, and the amnion beginning to be formed:—*a*, chorion; *b*, yelk-sac; *c*, embryo; *d* and *e*, folds of the serous layer rising up to form the Amnion.

Fig. 134.



The Amnion in process of formation, by the arching over of the serous lamina:—*a*, the chorion; *b*, the yelk-bag, surrounded by serous and vascular laminæ; *c*, the embryo; *d*, *e*, and *f*, external and internal folds of the serous layer, forming the amnion; *g*, incipient allantois.

these gradually approach one another, at last meeting in the space between the general envelop and the embryo, so as to form an additional investment to the latter. As each fold contains two layers of membrane, a double envelop is thus formed; of which the outer layer (Fig. 134, *d*, *e*, and Fig. 135, *h*), afterwards adheres to the inner surface of the chorion,—the original yelk-bag, or Zona pellucida, being now lost sight of; whilst the inner one (Fig. 134, *f*, *f*, and Fig. 135, *f*), remains as a distinct sac, to which the name of *Amnion* is given. This takes place during the third day in the Chick; but the period at which it occurs in the Human Ovum has not yet been clearly ascertained.

817. The embryo, like the adult, has need of Respiration; in order that the carbonic acid set free in the Nutritive operations may be removed from its fluids. In Fishes, the surrounding water acts with sufficient power upon the vessels of the yolk-bag, to produce the required aëration, up to the time when the gills of the young animal are ready to come into play. But in the higher oviparous animals, whose development proceeds further before they leave the egg, a more special provision is made for the purpose. A bag, termed the *allantois*, sprouts (as it were) from the lower end of the intestine (Fig.

134, g); and gradually enlarges, passing round the embryo (Fig. 135, g), so as in Birds almost completely to enclose it, intervening between the germinal membrane and the shell, and receiving the direct influence of the air that penetrates the latter. It is thus the temporary lung of the air-breathing oviparous animal; and it serves for the aëration of its fluids, up to the time when it quits the egg. In the Ovum of the Mammal, the chief office of the Allantois is to convey the vessels of the Embryo to the Chorion; and its extent bears a pretty close correspondence with the extent of surface, through which the Chorion comes into vascular connection with the Decidua,—this extent varying considerably in the different orders of Mammalia. Thus in the Carnivora, whose placenta extends like a band around the whole ovum, the allantois also lines the whole inner surface of the chorion, except where the umbilical vesicle comes into contact with it. On the other hand, in Man and the Quadrumana, whose placenta is restricted to one spot, the allantois is small, and conveys the fœtal vessels to one portion only of the Chorion. When these vessels have reached the Chorion, they ramify in its substance, and send filaments into its villi; and in proportion as these villi form that connection with the uterine structure which has been already described (§ 811), do the vessels increase in size. They then pass directly from the fœtus to the chorion; and the allantois, being no longer of any use, shrivels up like the Yelk-bag, and remains as a minute vesicle, only to be detected by careful examination. The lower part of it, however, pinched off (as it were) from the rest, remains as the Urinary bladder; and the Urachus or suspensory ligament of the latter represents the duct, by which the Allantois was originally connected with the abdominal cavity.

Fig. 135

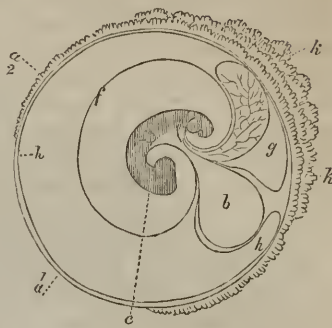


Diagram representing a Human Ovum in second month:—a, 1, smooth portion of chorion; a, 2, villous portion of chorion; k, k, elongated villi, beginning to collect into Placenta; b, yolk-sac or umbilical vesicle; c, embryo; f, amnion (inner layer); g, allantois; h, outer layer of amnion, coalescing with chorion.

818. The connection which is thus formed between the Vascular system of the fœtus and that of the parent, is the only one that exists in the lower Mammalia; which are thus properly designated as "non-placental." Each villus of the Chorion contains a capillary loop; this is enclosed in a layer of cells; and this again in a lamina of basement-membrane;—the whole forming the *fœtal* tuft. This comes into contact with the cellular decidua, which lies upon the basement-membrane covering the vascular layer of the decidua. Now the Placenta is composed of these very elements, arranged in a more complex manner. It is formed by an extension of the vascular tufts

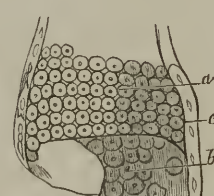
of the chorion at certain parts; and a corresponding adaptation, on the part of the Uterine structure, to afford to these an increased supply of nutritious fluid. These specially prolonged portions are scattered, in the Ruminants and some other Mammalia, over the whole surface of the Chorion, forming what are termed the Cotyledons; but in the higher orders, and in Man, they are concentrated in one spot, forming the Placenta. In some of the lower tribes, the maternal and fœtal portions of the placenta may be very easily separated; the former consisting of the thickened decidua; and the latter being composed of the prolonged and ramifying vascular tufts of the Chorion, which dip down into it. But in the Human placenta, the two elements are mingled together through its whole substance.

819. The Fœtal portion of the placenta consists of the branches of the umbilical vessels; which subdivide at the point at which they enter the mass, and form, by their minute ramifications, a large part of its substance. Each villus contains a capillary vessel, which forms a series of loops, communicating with an artery on the one side, and with a vein on the other; but the same capillary may enter several villi, before re-entering a larger vessel. The vessels of the villi (Fig. 136, *g*) are covered, as in the chorion, by a layer of cells, (*f*,) enclosed in basement-membrane (*e*); but the fœtal tuft thus

Fig. 136.

Extremity of a placental villus:—*a*, external membrane of the villus, continuous with the lining membrane of the vascular system of the mother; *b*, external cells of the villus, belonging to the placental decidua; *c*, *c*, germinal centres of the external cells; *d*, the space between the maternal and fœtal portions of the villus; *e*, the internal membrane of the villus, continuous with the external membrane of the chorion; *f*, the internal cells of the villus, belonging to the chorion; *g*, the loop of umbilical vessels.

Fig. 137.



Portion of the external membrane, with the external cells, of a placental villus:—*a*, cells seen through the membrane; *b*, cells seen from within the villus; *c*, cells seen in profile along the edge of the villus.

formed is enclosed in a second series of envelops (*a*, *b*, *c*), derived from the maternal portion of the placenta,—a space (*d*) being left between the two, however, at the extremity of the tuft. The vascular tufts not unfrequently extend beyond the uterine surface of the placenta, and dip down into the uterine sinuses, where they are bathed in the maternal blood. The Maternal portion of the Placenta may be regarded as a large sac, formed by a prolongation of the internal coat of the great Uterine vessels. Against the fœtal surface of this sac, the tufts just described may be said to push themselves,

so as to dip down into it, carrying before them a portion of its thin wall, which constitutes a sheath to each tuft. In this manner, the whole interior of the placental cavity is intersected by numerous tufts of fœtal vessels, disposed in fringes, and bound down by the membrane that forms its proper wall,—just as the intestines are covered and held in their places by the peritoneum. Now as this dilatation of the uterine blood-vessels carries the decidua before it, every one of the vascular tufts that dips down into it will be covered with a layer of the cellular structure of the latter (Fig. 137, and Fig. 138, *e*); and this will also form a part of all the bands that connect and tie down the tufts (Fig. 138, *g*). The blood is conveyed into the cavity of the placenta by the "curling arteries," so named from their peculiar course (Fig. 138, *c*), which proceed from the arteries of the uterus; and it is returned by large short straight trunks, which pass obliquely through the decidua (Fig. 138, *b*), and discharge their contents into the great uterine sinuses.

Fig. 138.

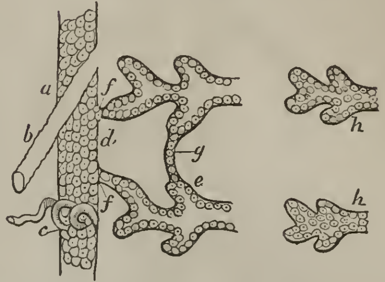
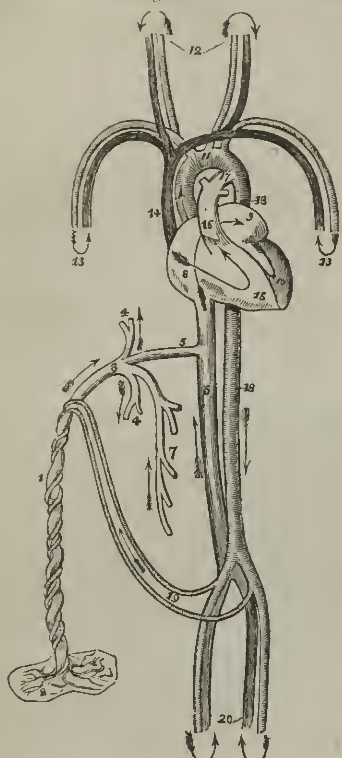


Diagram illustrating the arrangement of the placental decidua:—*a*, decidua in contact with the interior of the uterus; *b*, venous sinus passing obliquely through it by a valvular opening; *c*, a curling artery passing in the same direction; *d*, the lining membrane of the maternal vascular system, passing in from the artery and vein lining the bag of the placenta, and covering *e*, *e*, the fœtal tufts, passing on to them from their stems from the fœtal side of the cavity, also by the terminal decidual bars *f*, *f*, from the uterine side, and from one tuft to the other by the lateral bar, *g*; *h*, *h*, separated fœtal tufts, showing the internal membrane and cells, which, with the loops of umbilical vessels, constitute the true fœtal portion of the tufts.

820. There is no more direct communication between the Mother and Fœtus than this; all the observations, which have been supposed to prove a direct vascular continuity, being certainly fallacious. The function of the Placenta is manifestly double. The fœtal tufts draw, from the maternal blood, the materials which are required for the nutrition of the embryo,—these materials having been first selected and partially elaborated by the two sets of intervening cells: and in this character, the fœtal tufts resemble the villi of the intestinal surface, which dip down into the fluids of the alimentary canal, and absorb the nutritive material which they furnish. But the Placenta also serves as a respiratory organ; aërating the blood of the fœtus, by exposing it to the influence of the oxygenated blood of the Mother: and in this respect the fœtal tufts bear a close correspondence with the gills of aquatic animals, bringing the blood into relation with a surrounding fluid medium containing oxygen, which is imbibed by the blood in exchange for the carbonic acid given off.

821. The formation of the Human Placenta commences in the latter part of the second month of utero-gestation; during the third, it acquires its proper character; and it subsequently goes on increasing, in

Fig. 139.



The fœtal circulation 1. The umbilical cord, consisting of the umbilical vein and two umbilical arteries; proceeding from the placenta (2). 3. The umbilical vein dividing into three branches; two (4, 4) to be distributed to the liver; and one (5), the ductus venosus, which enters the inferior vena cava (6). 7. The portal vein, returning the blood from the intestines, and uniting with the right hepatic branch. 8. The right auricle; the course of the blood is denoted by the arrow, proceeding from 8 to 9, the left auricle. 10. The left ventricle; the blood following the arrow to the arch of the aorta (11), to be distributed through the branches given off by the arch to the head and upper extremities. The arrows 12 and 13, represent the return of the blood from the head and upper extremities through the jugular and subclavian veins, to the superior vena cava (14), to the right auricle (8), and in the course of the arrow through the right ventricle (15), to the pulmonary artery (16). 17. The ductus arteriosus, which appears to be a proper continuation of the pulmonary artery; the offsets at each side are the right and left pulmonary artery cut off; these are of extremely small size as compared with the ductus arteriosus. The ductus arteriosus joins the descending aorta (18, 18), which divides into the common iliacs, and these into the internal iliacs, which become the hypogastric arteries (19), and return the blood along the umbilical cord to the placenta; while the other divisions, the external iliacs (20), are continued into the lower extremities. The arrows at the terminations of these vessels mark the return of the venous blood by the veins to the inferior cava.

accordance with the growth of the ovum. The vessels of the Uterus undergo great enlargement throughout; but especially at the part to which the Placenta is attached; and the blood, in moving through them, produces a peculiar murmur, which is usually audible with distinctness at an early period of pregnancy, and which may be regarded (when due care is taken to avoid sources of fallacy) as one of its most unequivocal physical signs. The sound is most commonly heard near the situation of the Fallopian tube of the right side; and it corresponds with the pulse of the mother.

822. It would be inconsistent with the character and objects of this Treatise, to follow, in any detail, the history of the development of the Fœtus, during its intra-uterine life; and a general account of the evolution of most of the chief organs, is given in connection with that of their structure. The condition of the Circulating apparatus, however, at the period of birth, deserves especial notice. A general account of the development of the simple pulsating trunk, which constitutes its first form, into the four-cavitied heart of the higher Vertebrata,—and of the conversion of the single trunk proceeding from it, with its four pairs of branchial arches, into the aorta and pulmonary arteries, with their chief subdivisions, has been already given (§ 566). Up to the time of birth, however, the partition between the Auricles is incomplete; a large aperture, the *foramen ovale*, existing in it. There is also a direct communication between the pulmonary artery and the aorta, by the *ductus arteriosus;* and another direct

channel between the umbilical vein and the vena cava, by the *ductus venosus*.

823. The following is the course of the Circulation of the Blood in the Fœtus. The fluid brought from the placenta by the umbilical vein (Fig. 139, 3), is partly conveyed at once to the vena cava ascendens, by means of the ductus venosus (5), and partly flows through two trunks (4, 4), that unite with the portal vein (7), returning the blood from the intestines, into the substance of the liver, thence to be returned to the vena cava by the hepatic vein. Having thus been transmitted through the two great depurating organs, the placenta and the liver, the blood that enters the vena cava is purely arterial in its character; but being mixed in the vessels with the venous blood that is returned from the trunk and lower extremities, it loses this character in some degree, by the time that it reaches the heart. In the right auricle, which it then enters, it would also be mixed with the venous blood which is brought down from the head and upper extremities by the descending cava; were it not that a very curious provision exists, to impede (if it does not entirely prevent) any further admixture. This consists in the arrangement of the Eustachian valve; which directs the *arterial* current (that flows upwards through the ascending cava) into the *left* side of the heart, through the foramen ovale: whilst it directs the *venous* current (that is being returned by the descending cava) into the *right* ventricle. When the ventricles contract, the arterial blood contained in the left is propelled into the ascending Aorta, and supplies the branches that proceed to the head and upper extremities, before it undergoes any further admixture: whilst the venous blood contained in the right ventricle, is forced into the Pulmonary artery, and thence through the ductus arteriosus (17) which is like a continuation of its trunk, into the descending aorta, mingling with the arterial current which that vessel previously conveyed, and thus supplying the trunk and lower extremities with a mixed fluid. A portion of this is conveyed, by the umbilical arteries, to the Placenta; in which it undergoes the renovating influence of the maternal blood; and from which it is returned in a state of purity.

824. Hence the head and superior extremities, whose development is required to be in advance of that of the lower, are supplied with blood nearly as pure as that which returns from the placenta; whilst the rest of the body receives a mixture of this, with what has previously circulated through the system. The Pulmonary arteries convey little or no blood through the lungs; the current of blood, propelled from the right ventricle, passes directly onwards through the ductus arteriosus, into the aorta.—At birth, however, the course of the circulation undergoes great changes, that it may be adapted to the new mode, in which the infant is henceforth to obtain its nutrition and to carry on its respiration. As soon as the lungs are distended by the first inspiration, a portion of the blood of the pulmonary artery is diverted into them, and there undergoes aëration; and, as this proportion increases, with the full activity of the lungs, the ductus arte-

riosus gradually shrinks, and its cavity finally becomes obliterated. At the same time, the foramen ovale is closed by a valvular fold; and thus the direct communication between the two auricles is cut off. When these changes have been accomplished, the circulation which was before carried on upon the plan of that of the higher Reptiles (§ 563) becomes that of the complete warm-blooded animal; all the blood which has been returned in a venous state to the right side of the heart, being transmitted through the lungs, before it can reach the left side, or be propelled from its arterial trunks.—It is by no means unfrequent, however, for some arrest of development to prevent the completion of these changes; and various malformations, involving an imperfect discharge of the circulating and respiratory functions, may hence result.

825. The average length of time, which elapses between Conception and Parturition, in the Human female, appears to be 280 days, or 40 weeks. There can be little doubt, however, that Gestation may be occasionally prolonged for one, two, or even three weeks, beyond that period; such prolongation not being at all unfrequent amongst the lower animals; and numerous well-authenticated instances of it, in the Human female, being upon record. Upon what circumstances this departure from the usual rule is dependent, has not yet been ascertained; but it is a remarkable circumstance, ascertained by the observations of cattle-breeders, that the *male* has an influence upon the length of gestation,—a large proportion of cows in calf by certain bulls exceeding the usual period, and a small proportion falling short of it. Hence we must attribute the prolongation of the period to some peculiarity in the embryo, derived from its male parent.

826. The shortest period at which Gestation may terminate, consistently with the life of the child, has not been precisely ascertained; the difficulty of determining the precise date of conception being usually such, in this case as in the preceding, as to prevent the exact length of the Gestation from being known. Thus, the commencement of pregnancy being fixed by the time of the cessation of the Catamenia, when there is no more definite guide, it is obvious that the act of Conception may have taken place during any part of the interval that has elapsed since the last monthly period; and thus a doubt may exist as to the length of the Gestation, to the extent of from one to three weeks. There are very satisfactory cases on record, in which, from the degree of development of the infant at birth, as well as from other circumstances, it might be certainly known not to have attained 26 or 27 weeks, or little more than six months; and in which, by careful treatment, the infant was reared in a condition of health and vigour. And there is reason to believe, that infants have lived for some time, and might probably have been reared under better management, that were born as early as the 24th or 25th week.

827. The act of Parturition, by which the fœtus is expelled from

the Uterus, is accomplished in part by the contractile power of the Uterus itself; and in part by the combined operation of the various muscles, which press upon the abdominal cavity, and which effect the expulsion of the feces and urine. No account can be given of the reasons, why this change should take place at the period, which has been mentioned as its usual date; but we are as much in the dark in regard to other *periodic* phenomena of Animal life. For some days previously to the commencement of labour, there is usually a slow contraction of the fibres of the fundus and body of the uterus; and a yielding of those of the cervix; so that the child lies lower, and the size of the abdomen diminishes. This slow contraction is probably not dependent upon any act of the nervous system; but upon the *direct* excitement of the contractility of the muscular substance of the uterus. When labour properly commences, however, the Spinal system of nerves comes into play, and the uterine contractions are of a reflex nature. As before, however, the act of contraction is confined to the fundus and body of the uterus; the fibres of the cervix uteri, and of the vagina, being in a state of relaxation, which allows them to yield to the pressure of the child's head. In the first stage of labour, the Uterine contractions appear to be alone concerned; and it is not until the head of the child is passing through the os uteri, and is entering the vagina, that the assistance of the abdominal muscles is called in. These act, in the first instance, as in ordinary expiration; but their power is much increased by the voluntary retention of the breath, so that the whole of their contractile force may be applied to the expulsion of the fœtus. In a latter stage of labour, this retention of the breath becomes involuntary, during the accession of the "pains;" and the expulsion of the fœtus is commonly effected with considerable force, especially if the previous resistance has been considerable.

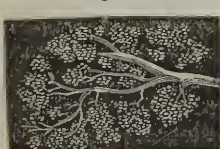
828. The same action which expels the fœtus, usually detaches the placenta; and if the uterus contract with sufficient force, after this has been thrown off, the orifices of the vessels which communicated with it are so effectually closed, that little or no hemorrhage from that source takes place. When efficient contractions do not occur, they may frequently be excited by pressure upon the uterus itself; by the application of cold to the abdominal surface, to the extremities, and (in severe hemorrhage) to the entire body; or by the application of the child to the nipple, which will frequently at once succeed in producing the desired effect. The efficacy of these means,—the latter in particular,—obviously depends upon the influence of the spinal system of nerves upon the muscular fibres of the uterus; the application of cold to the surface, or the irritation of the nipple, occasioning a reflex action in the uterus. But it is probable that this organ has also considerable power of contracting, independently of the nervous system; thus there are well-authenticated cases on record, in which the fœtus has been expelled after the *somatic* death (§ 65) of the parent; which must have been in consequence of the persistence of the independent

contractility of the Uterus, and the relaxed state of all the parts through which the child had to make its exit.

829. The cause of the occasional occurrence of the parturient efforts at an unusually early period, is as little understood as that of their ordinary action. There are some individuals, in whom this regularly happens at a certain month; so that it seems to be an action natural to them. In many cases, however, it may be traced to some undue exertion of body, or mental excitement; and not unfrequently to a general constitutional irritability, which renders the system liable to be deranged by very trifling causes. Premature labour is almost always to be prevented, if possible; being injurious alike to both mother and child; and for this prevention we have chiefly to rely upon rest and tranquillity of mind and body, and upon the careful avoidance of all those exciting causes, which are liable to produce uterine contractions by their operation upon the nervous system; whilst, at the same time, any measures which will invigorate the body, without stimulating it, should not be overlooked.

830. A peculiar preparation is made, in the females of the class Mammalia, for the sustenance of the infant, for a long period after birth. This consists in the secretion of a fluid, from the glands, termed *Mammary*, which contains all the elements that are required for the development of the body of the infant, during the first year. These glands present themselves in an almost rudimentary state, in some of the non-placental animals of the class; consisting only of a few large follicles, which open separately upon the surface (Fig. 106). In the higher Mammalia, however, we find it composed of vast numbers of minute follicles, clustered together upon excretory ducts. The general arrangement of these, in the human subject, is seen in Fig. 140; and in Fig. 111, the character of the follicles themselves, and of the secreting epithelial cells they contain, as seen under a much higher magnifying power, has been already shown. Each Mammary gland consists of a number of glandulæ, which are held together by areolar and fibrous tissue; this arrangement may probably have reference to the mobility, which it is requisite that the different parts of the mass should possess, one upon the other, in consequence of its situation upon the pectoralis muscle. The ducts converge and unite together; so as at last to form ten or twelve principal trunks, which terminate in the nipple. At the base of the nipple, these tubes dilate into reservoirs, which extend beneath the areola, and to some distance into the gland, when the breast is in a state of lactation. These, which are much larger in many of the lower Mammalia than they are in the Human female, seem to have for their office to contain a store of milk, sufficient to supply the immediate wants of the child when it is first applied to the breast; so that

Fig. 140.



Termination of portion of milk-duct in follicles; from a mercurial injection, by Sir A. Cooper; enlarged four times.

it shall not be disappointed, but shall be induced to proceed with sucking, until the *draught* be occasioned (§ 836).

831. The Mammary gland may be detected at an early period of fœtal existence, and it then presents no difference in the male and female; and it continues to grow, in each sex, in proportion to the body at large, up to the period of puberty. At that epoch, however, the gland begins to undergo a great enlargement in the female; and by the age of twenty, it attains its full size previous to lactation. Even then, however, the milk-follicles cannot be injected from the tubes. During pregnancy, the mammary glands receive a greatly-increased quantity of blood. This determination often commences very early; and produces a feeling of tenderness and distension, which is a valuable sign (where it occurs in conjunction with others) of conception having taken place. The vascularity of the gland continues to increase during pregnancy; and, at the time of parturition, its lobulated character can be distinctly felt. The follicles cannot be readily injected, however, until the gland is in a state of complete functional activity; i. e., during lactation.—The Mammary gland of the Male does not undergo this increase of development, except under certain peculiar circumstances to be presently noticed (§ 836); and it remains a sort of miniature picture of that of the female, varying in diameter from that of a large pea to an inch or even two inches.

832. The Milk, secreted by the Mammary glands, consists of Water, holding in solution the peculiar albuminous substance termed *Casein* (§ 176), and various Saline ingredients, together with (in most cases) a certain form of Sugar; and having Oleaginous globules suspended in it. These globules appear to be surrounded by a thin pellicle, which keeps them asunder, so long as the milk remains at rest.—The existence of these elements in ordinary Milk, as that of the Cow, is made apparent by the processes to which it is subjected in domestic economy. If it be allowed to stand for some time, exposed to the air, a large part of the oleaginous globules come to the surface, in consequence of their inferior specific gravity; and thus is formed the *cream*, which includes also a considerable amount of casein, with the sugar and salts of the milk. These may be partly separated by the continued agitation of the cream, as in the process of churning; this, by rupturing the envelops of the oil-globules, separates it into *butter*, formed by their aggregation, and *buttermilk*, containing the casein, sugar, &c. A considerable quantity of casein, however, is still entangled with the oleaginous matter; and this has a tendency to decompose, so as to render the butter rancid. It may be separated by keeping the butter melted at a temperature of 180°; when the casein will fall to the bottom, leaving the butter pure and much less liable to change,—an operation which is commonly known as the *clarifying* of butter. The Milk, after the cream has been removed, still contains the greater part of its casein and sugar. If it be kept long enough, a spontaneous change takes place in its composition; an incipient change in the casein being the cause of the conversion of

the sugar into lactic acid; and this coagulating the casein, by precipitating it in small flakes. The same precipitation may be accomplished at any time by the agency of various acids, especially the acetic, which does not act upon Albumen; but Casein cannot be coagulated like albumen, by the influence of heat alone. The most complete coagulation of Casein is effected by the agency of the dried stomach of the calf, known as *rennet;* which exerts so powerful an influence, as to coagulate the casein of 1,800 times its weight of milk. It is thus that, as in the making of cheese, the *curd* is separated from the *whey;* the former consisting chiefly of the casein; whilst the latter contains a large proportion of the saline and saccharine matter, which entered into the original composition of the milk. These may be readily separated by evaporation.

833. The chief characters of Casein have been already stated (§ 176).—Its Oleaginous matter consists, like the fats in general, of the two substances, elaine and stearine; but it also contains another substance peculiar to it, which is termed *butyrine.* This last (to which the characteristic smell and taste of butter are due) is converted by saponification into three volatile acids, of strong animal odour, to which the names of butyric, capric, and caproic acids have been given. This change may be effected, at any period, by treating the butyrine with alkalies; but it may also take place by spontaneous decomposition, which is favoured by time and moderate warmth.—The Sugar of Milk is peculiar as containing nearly 12 per cent. of water; so that it may be considered as really a *hydrate of sugar.* It is nearly identical in its composition with starch; and may, like it, be converted into true sugar by the agency of sulphuric acid. But it is chiefly remarkable for its proneness to conversion into lactic acid, under the influence of a *ferment* or decomposing azotized substance.—The Saline matter contained in Milk appears to be nearly identical with that of the blood; with a larger proportion, however, of the phosphates of lime and magnesia, which amount to 2 or 2½ parts in 1000. These are held in solution chiefly by the Casein, which has a remarkable power of combining with them.

834. Thus ordinary Milk contains the three classes of organic principles, which form the chief part of the food of animals,—namely, the albuminous, the saccharine, and the oleaginous; together with the mineral elements, which are required for the development and consolidation of the fabric of the infant. It would appear, however, that the combination of all these is not necessary; but rather has reference to the composition of the food, on which the animal is destined to be afterwards supported. Thus it has been lately shown that, in the Carnivora, the milk contains no sugar; which principle is altogether wanting in the food of the adult. Amongst the different species of Herbivorous animals, the proportion of the several ingredients varies considerably; and it is also liable to considerable variation in accordance with the nature of the food, the amount of exercise taken by the animal that affords it, and other circumstances. Thus in the milk of

the Cow, Goat, and Sheep, the average proportions of Casein, Butter, and Sugar are nearly the same one with another, each amounting to from 3 to 5 per cent. In the milk of the Ass and Mare, on the other hand, the proportion of Casein is under 2 per cent., the oleaginous constituents are scarcely traceable, whilst the sugar and allied substances rise to nearly 9 per cent. In the Human female, the saccharine and oleaginous elements are both present in large amount; whilst the Casein forms a moderate proportion.—The proportion of the saccharine and oleaginous elements appears to be considerably affected by the amount in which these are present in the food; and by the degree in which the quantity ingested is consumed by the respiratory process. Thus, a low external temperature, and out-door exercise, by increasing the production of carbonic acid from the lungs, occasion the consumption of the oleaginous and saccharine matters, which might otherwise pass into the milk, and thus diminish the amount of cream. On the other hand, exercise favours the secretion of casein; which would seem to show, that this ingredient is derived from the disintegration of the azotized tissues. Thus in Switzerland, the cattle which pasture in exposed situations, and which are obliged to use a great deal of muscular exertion, yield a very small quantity of butter, but an unusually large proportion of Cheese; yet the same cattle, when stall-fed, give a large quantity of butter, and very little cheese.

835. The Milk first secreted after parturition, known as the *Colostrum*, is very different from ordinary milk; and possesses a strongly purgative action, which is useful in clearing the bowels of the infant from the various secretions which have accumulated in them at birth, constituting the *meconium*. The Colostrum, when examined with the Microscope, is found to contain a multitude of large yellow granulated corpuscles; each of which seems composed of a number of small grains aggregated together. The colostric character is sometimes retained for some time after birth, and severely affects the health of the infant. This may happen without any peculiarity in the ordinary characters of the secretion, which has all the appearance of healthy milk; but the Microscope at once detects the difference, by the presence of the colostric corpuscles.

836. The formation of this Secretion is influenced by the Nervous system, to a greater degree, perhaps, than that of any other. The process may go on continuously, to a slight degree, during the whole period of lactation; but it is only in animals that have special reservoirs for the purpose, that any accumulation of the fluid can take place. In the Human female, as we have seen, these are so minute as to hold but a trifling quantity of milk; and the greater part of the secretion is actually formed, whilst the child is at the breast. The irritation of the nipple produced by the act of suction, and the mental emotion connected with it, concur to produce an increased flow of blood into the gland, which is known to Nurses as the *draught;* and thus the secretion is for the time greatly augmented. The draught

may be produced simply by the emotional state of mind, as by the thought of the child when absent; and the irritation of the nipple may alone occasion it; but the two influences usually act simultaneously. The most remarkable examples of the influence of such stimuli on the Mammary secretion, are those in which milk has been produced by girls and old women, and even by men, in quantity sufficient for the support of an infant. The application of the child to the nipple in order to tranquilize it, the irritation produced by its efforts at suction, and the strong desire to furnish milk, seem in the first instance to occasion an augmented nutrition of the gland, so that it becomes fit for the performance of its function; and then to produce in it that state of functional activity, the result of which is the production of Milk.

837. It is not only in this way, that the Mammary secretion is influenced by the condition of the mind; for it is peculiarly liable to be affected as to quality, by the habitual state of the feelings, or even by their temporary excitement. Thus a fretful temper not only lessens the quantity of milk, but makes it thin and serous, and gives it an irritating quality; and the same effect will be produced for a time by a fit of anger. Under the influence of grief or anxiety, the secretion is either checked altogether, or it is diminished in amount, and deteriorated in quality. The secretion is usually checked altogether by terror; and under the influence of violent passion, it may be so changed in its characters, as to produce the most injurious and even fatal consequences to the infant. So many instances are now on record, in which children, that have been suckled within a few minutes after the mothers have been in a state of violent rage or terror, have died suddenly in convulsive attacks, that the occurrence can scarcely be set down as a mere coincidence; and certain as we are of the deleterious effects of less severe emotions upon the properties of the milk, it does not seem unlikely that, in these cases, the bland nutritious fluid should be converted into a poison of rapid and deadly operation.

838. Of the quantity of Milk ordinarily secreted by a good Nurse, it is impossible to form any definite idea; as the amount which can be artificially drawn, affords no criterion of that which is ordinarily secreted at the time of the draught. The quantity which can be squeezed from either breast at any one time, and which, therefore, must have been contained in its tubes and reservoirs, is about two ounces. The amount secreted will depend upon several circumstances; such as the nature and amount of the ingesta; the state of bodily health; and the condition of the mind. An adequate but not excessive amount of nutritious food, in which the farinaceous, oleaginous, and albuminous principles are duly blended; a vigorous but not plethoric constitution, regular habits, and moderate exercise; together with a cheerful and tranquil temper; altogether produce the most beneficial influence upon the secretion. It is seldom that stimulating liquors, which are so commonly indulged in, are anything but prejudicial; but the unmeasured condemnation of them, in which

some writers have indulged, is certainly injudicious; as experience amply demonstrates the improvement in the condition both of mother and infant, which *occasionally* results from the moderate employment of them.—In the administration of medicines to the mother, it is very desirable that the tendency of soluble saline substances to pass into the milk, and thus to affect the child, should be borne in mind. The vegetable substances used in medicine seem to have much less disposition to pass off by this secretion; and they are consequently to be preferred during lactation.

839. From the close correspondence which exists between the elements of the Milk and those of the Blood, it is evident that we cannot expect to trace the existence of the former, as such, in the circulating current. It is interesting, however, to remark, that a preparation appears to be taking place in the laboratory of the system, for the production of this secretion, long before the period of parturition. The Urine of pregnant women almost invariably contains a peculiar substance termed *kiestine*, which is nearly related to casein, and which disappears from the urine as soon as lactation has fully commenced. It would seem, therefore, that a compound of this nature is in course of preparation during pregnancy; and that it is eliminated by the kidney until the Mammary Gland is prepared for the active performance of its function.—That the kidney may relieve the system from the accumulation of other constituents of the mammary secretion, appears from a case recently put on record; in which the urine of a parturient female, who did not suckle her infant, was found to contain a considerable quantity of butyric acid, during several days. There can be no doubt that in ordinary states of the system, this secretion cannot be required for the depuration of the blood; since it does not occur in the male at all, and is present in the female at particular times only. But these facts afford ground to believe that, when the process is going on, certain products are generated in the system, which are not found there at other times. And it is quite certain that the sudden checking of the secretion, or the re-absorption of the fluid already poured out, occasioning an accumulation of these substances in the circulating current, may give rise to very injurious consequences. Some very curious instances are on record, in which a transference of the secreting power to some other surface has taken place under such circumstances; so as to relieve the system from the accumulation in question.

CHAPTER XII.

OF THE NERVOUS SYSTEM.

1. *General View of the operations, of which the Nervous System is the instrument.*

840. We have now considered the entire series of those operations, which make up the *vegetative* or *organic* life of the Animal; including the functions by which the germ is prepared, by which it is nourished until it can be left to its own powers, by which its continued development is effected until the fabric characteristic of the adult has been built up, and by which the normal constitution is maintained through a lengthened period,—so long as the necessary materials are supplied, and no check or hindrance is interposed, by external influences, to that regular sequence of change, on which the continuance of its powers depends. In this survey it will have been perceived, that the *essential* parts of these operations are, in Animals as in Plants, completely independent of the influence of that, which constitutes the peculiar endowment of Animals; namely, the Nervous System.

a. The *Reduction* of the food in the Stomach, by the solvent power of the gastric fluid, is a purely chemical operation, with which the Nervous System has nothing whatever to do, excepting that it perhaps accelerates the process, by stimulating the Muscular coat of the stomach to that peculiar series of contractions, which keeps the contents of the cavity in continual movement, and *favours* the action of the solvent upon it.

b. With the process of *Absorption*, by which the nutritive materials, with other substances, are introduced into the vessels, the Nervous System has nothing to do; this being a purely vegetative operation, partly dependent upon the simple physical conditions which produce Endosmose, and partly on a process of cell-growth.

c. The *Assimilation* of the new material, effected, as we have seen reason to believe, by another set of independent cells, can receive but little influence from the Nervous System, and is obviously capable of taking place without its aid.

d. The *Circulation* of the Blood, again, though dependent in part upon the impulsive power of a Muscular organ, the Heart, is not on that account brought into closer dependence upon the Nervous System; for we have seen that the contractions of the heart result from its own inherent powers, so as to continue after it has been completely detached from the body; and that the *capillary power*, which is the chief agent in the movement of the blood in the lower animals, and which exerts an important subsidiary action in the higher, is the result of

the exercise of certain affinities, between the blood and the surrounding tissues, in which the Nervous System can have no immediate concern.

e. The act of *Nutrition*, in which every tissue draws from the circulating blood the materials for its own continued growth and development, and by which it incorporates these with its own substance, is but a continuance of the same kind of operation, as that which takes place in the early development of the embryo, long anteriorly to the first appearance of the nervous system,—namely, a process of cell-development and metamorphosis, which must be, from its very nature, independent of Nervous agency.

f. The same may be said of the *Secreting* operation in general; for this essentially consists of the separation of certain products from the blood, by cells situated upon free surfaces; which thus remove those products from the interior of the fabric.

g. And the interchange of oxygen and carbonic acid, which takes place between the atmosphere and the venous blood, when brought into mutual relation in the lungs, and which is the essential part of the function of *Respiration*, is an operation of a merely physical character, with which the Nervous system can have no direct concern.

h. Finally, the development of the reproductive germs in the one sex, and of the ova within which these are to be evolved in the other, the subsequent fertilization of the latter by the former, and the changes consequent upon that act, together making up the function of *Reproduction*, may be all regarded as modifications of the ordinary Nutritive processes; and are effected, like these, by the inherent powers of the parts concerned in them, at the expense of the materials supplied by the blood, without any direct dependence upon the Nervous system.

841. Still, although the various processes, which make up the *essential* part of the nutritive operations, in Animals as in Plants, are no more dependent on any peculiar influence derived from a Nervous system, in the former, than they are in the latter, it must be evident, from the details already given, that there must be in Animals various *accessory* changes, which are requisite for the continuance of the former, and which can only be effected by the peculiar powers with which Animals are endowed.—Thus, to commence with Digestion;—this preliminary process, which the nature of the food of the plant renders unnecessary for *its* maintenance, can only be accomplished by the introduction of the food into a cavity or sac, in which it may be submitted to the action of the solvent fluid. The operation of *grasping* and *swallowing* the food, wherever it is performed, is accomplished through the agency of the Nervous system; and if it be checked by the loss of Nervous power, the Digestive process must cease for want of material.—So, again, although interchange of gaseous ingredients between the atmosphere and the circulating fluid may take place with sufficient energy in Plants and the lower Animals, through the mere exposure of the general surface to the atmosphere, yet we find that,

in all the higher Animals, certain movements are requisite, for the continual renewal of the air or water which are in contact with one side of the respiratory surface, and of the blood which is in relation with the other: for the direction of which movements, a Nervous system is requisite.—In the excretory processes, moreover, the removal of the effete matters from the body can only be accomplished, in the higher Animals, by certain combined movements; the object of which is to take up the products that are separated by the action of the proper secreting cells, and to carry them to the exterior of the body, there to be set free; and these combined movements can only be effected by the agency of the Nervous system.—Lastly, in the act of Reproduction, the arrangement of the sexual organs in Animals, requires that a certain set of movements should be adapted to set free the germ from the body of the male, and to convey it to the ovule of the female; and further, that the ovum should be expelled from the body of the latter, in a state of more or less advanced development. For these movements a special arrangement is made, in the construction of the Nervous system, and in the application of its peculiar powers.

842. Thus we see that, although the Organic functions of the Animal are essentially independent of the Nervous System, this system affords the conditions which are requisite for their continued maintenance; being the instrument by which the muscles are called into action for the performance of the various combined actions that constitute the *mechanism* (so to speak), by which the Vegetative part of the fabric is combined with the Animal portion of the organism. We are not to suppose, however, that *every* movement which takes place in the Animal body is dependent upon the Nervous System; for we have seen that the Muscular tissue may be employed to perform contractions excited by stimuli applied to itself, and that it may thus execute a set of movements in which the nervous system has no direct participation. And it is desirable that the Student should observe, that these are, in all instances, those most *directly* connected with the Vegetative functions, and, at the same time, those of the simplest and most straightforward character.—Thus, the peristaltic movement, by which the alimentary and fecal matters are propelled along the Intestinal tube, results from the *direct* excitement of the contractility of its muscular walls, and is entirely independent of Nervous agency; and this movement is accomplished by the successive contraction of the different fasciculi surrounding the tube, which take up (as it were) each other's action (§ 352). So, again, the successive contractions and dilatations of the cavities of the Heart, which perform so important a part in the Circulation of the blood, are the result of the properties inherent in that organ; the muscular fibres of which are excited to a peculiar rhythmical and consentaneous contraction, by the flow of blood into the cavities when dilating. Moreover, in the Excretory ducts of various glands, we find a Muscular coat, by which the fluids secreted in the glands, are propelled towards

their outlet on the exterior of the body, or on one of its free internal surfaces.

843. In these instances, then, we observe that the simple Contractility of Muscular structure, excited by *direct* stimulation, is applied to effect the movements most closely connected with the Organic functions. With the processes, therefore, which take place in the *penetralia* of the system, the Nervous System has no direct concern. Its office is to guard the *portals* for entrance and exit; and to fill those chambers, which admit the new materials from the external world; or to empty the receptacles, which collect from the interior of the system the effete matters that are to be cast out from it. And we find that, for these offices, the Nervous system is employed in its very simplest mode of operation;—that which does not involve Sensation, Intelligence, Will, or even Instinct (in the proper sense of that term), but which may take place independently of all consciousness,—by the simple *reflexion* of an impression, conveyed *to* a ganglionic centre by one set of fibres proceeding towards it from the circumference along another set which passes *from* it to the muscles, and calls them into operation (§ 394). This reflex function, therefore, is the simplest application of the Nervous System in the Animal body. We shall presently see reason to believe, that a very large proportion of the movements of many of the lower animals are of this reflex character; and that they are not necessarily accompanied by sensation, although this may usually be aroused by the same cause which produces them. As we rise, however, in the scale of Animal existence, we find the *reflex* movements forming a smaller and smaller proportion of the whole; until, in Man, they constitute so limited a part of the entire series of movements of which the Nervous system is the agent, that their very existence has been overlooked.

844. But the main purpose of the Nervous System is to serve as the instrument of the *Psychical** powers, which are the distinguishing attribute of the Animal. It has been already pointed out, that the possession of *Consciousness* (or of the capability of receiving sensations), and the power of executing Spontaneous Movements (that is, movements which are not immediately dependent upon external stimuli), constitute the essential features in which the Animal differs from the Plant. All the other differences in structure, that respectively characterize these two classes of living beings, are subordinate to this one leading distinction,—the presence of a Nervous system, and of its peculiar attributes in the one,—and its absence in the other. Now when we attempt to analyze these peculiar attributes, we may resolve them, like the properties of the material body, into different groups. We find that the *first* excitement of all mental changes, whether these involve the action of the *feelings* or of the *reason*, depends upon *sensations;* which are produced by impressions made upon the nerves of

* This term, derived from the Greek ψυχη, is used to designate the sensorial and mental endowments of Animals, in the most comprehensive acceptation of those terms.

certain parts of the body, and are conveyed by these to a particular ganglionic centre, which is termed the *sensorium*,—being the part in which Sensation, or the capability of *feeling* external impressions, especially resides.

845. Now there are numerous actions, especially among the lower Animals, which seem to be as far removed from the influence of the Will, and as little directed by Intelligence, as the Reflex movements themselves; but which, nevertheless, depend upon sensation for their excitement. The sensation may *immediately* direct the movement; or it may excite an emotion or desire, which, without any calculation of consequences, any intentional adaptation of means to ends, any exertion of the reason, or any employment of a discriminating Will, may produce an action, or train of actions, as directly and obviously adapted to the well-being of the individual, as we have seen those of the reflex character to be. It is impossible to say, in regard to many of the actions of the lower animals, to what extent they involve feelings or emotions, at all analogous to those which *we* experience; and it would seem better to apply the generic term *Consensual* to those in which the Sensation excites the motor action, either immediately, or through the agency of an indiscriminating Desire excited by the sensation. This class will include all the purely Instinctive actions of the lower Animals; which make up, with the reflex, nearly the whole of the Animal functions in many tribes; but which are found to be gradually brought under subordination to the Intelligence and Will, as we rise towards Man, in whom those faculties are most strongly developed, so as to keep the Consensual as well as the Reflex actions quite in subordination to the more elevated purposes of his existence.

846. There are many sensations, however, which do not thus immediately give rise to muscular movements; their operation being rather that of stimulating to action the Intellectual powers. There can be little doubt that *all* Mental processes are dependent, in the first instance, upon Sensations; which serve to the Mind the same kind of purpose, that food and air fulfil in the economy of the body. If we could imagine a being to come into the world with its mental faculties fully prepared for action, but destitute of any power of receiving sensations, these faculties would never be aroused from the condition in which they are in profound sleep; and the being must remain in a state of complete unconsciousness, because there is nothing of which it can be made conscious, no kind of *idea* which can be aroused within it. But after the mind has once been in active operation, the destruction of all *future* power of receiving sensations would not reduce it again to the inactive condition. For sensations are so stored up in the mind, by the power of Memory, that they may give rise to ideas at any future time; and thus the mind may feed (as it were) upon the *past*. Now the ideas which are excited by sensations, and which are coloured by the state of Feeling which accompanies them, become the subjects of Reasoning processes more or less complex, sometimes of the utmost brevity and simplicity, sometimes of the most

refined and intricate nature. These reasoning processes, when they result in a determination to execute a particular movement, execute that movement by an act of Volition; the peculiar character of which is, that it is the expression of a definite *purpose*, of a *designed* adaptation of means to ends, on the part of the individual performing it; instead of being the result of mere blind indiscriminating impulse, which seems to be the main-spring of the instinctive operations. It is in Man, that we find the highest development of the reasoning faculties; but it is quite absurd to limit them to him, as some have done; since no impartial observer can doubt, that many of the lower animals can execute reasoning processes, as complete in their way as those of Man, though much more limited in their scope.

847. Thus, then, we have to consider the Nervous system under three heads;—*first*, as the instrument of the Reflex actions;—*second*, as the instrument of the Consensual and Instinctive actions;—*third*, as the instrument of the Intellectual processes, and of Voluntary movements. Now there is good reason to believe, that to each of these groups of actions a particular portion of the Nervous Centres, with its afferent and efferent nerves, may be assigned;—one ganglion, or collection of ganglia, being the instrument of the Reflex actions; another of the Consensual and Instinctive operations; and a third of the Intellectual powers, and of the Voluntary movements to which they give rise. In order that the relations of these subdivisions may be better understood, it will be desirable to take a brief survey of the comparative structure of the Nervous system in the principal groups of Animals; and to inquire what actions may be justly attributed to its several parts in each instance; commencing with those in which the structure is the simplest, and the variety of actions the smallest; and passing on gradually to those, in which the structure is increased in complexity by the addition of new and distinct parts, and in which the actions present a corresponding variety.

2. *Comparative Structure and Actions of the Nervous System.*

848. From what has been already said (§ 373-9) of the characters of the two elementary forms of the Nervous Tissue, it is evident that no Nervous System can exist, in which both these forms should not be present. We look, therefore, for *ganglia*, composed of the *vesicular* nervous substance, and serving as the centres of nervous power; and for cords or *trunks*, composed of the *tubular* substance, and serving to communicate between the ganglia and the parts with which they are to be functionally connected. Now it is quite certain that, at present, no such Nervous apparatus can be detected in many of the lowest Animals; and some Physiologists have had recourse to the supposition of their possessing a "diffused" nervous system,—that is, of their possessing nervous particles, in a separate form, incorporated as it were with their tissues. But we have seen, that each tissue possesses its own properties, and can perform its own actions,

independently of the rest;—that even the contractility of Muscular fibre is by no means dependent upon the Nervous system, though usually called into play through its means;—and that the simplest office of a Nervous System is to produce a muscular movement in respondence to a certain impression; which action requires that it should have an *internuncial* or communicating power, only to be exercised (so far as we at present know) by continuous fibres. The apparent absence of a Nervous system is doubtless to be attributed, in many instances, to the general softness of the tissues of the body, which prevents it from being clearly made out among them. And it is to be remembered, that, on the principles already stated, we should expect to find it bearing a much smaller proportion to the entire structure, in the lowest Animals, whose functions are chiefly Vegetative,—than in the highest, in which the vegetative functions seem destined merely for the development of the Nervous and Muscular systems, and for the sustenance of their powers.

849. Among the *Radiated* classes, the parts of whose bodies are arranged in a circular manner around the mouth, and repeat each other more or less precisely, the Nervous system presents a corresponding form. In the Star-fish, for example, which is one of the highest of these animals, it forms a ring, which surrounds the mouth; this ring consists of nervous cords, which form communications between the several ganglia, one of which is placed at the base of each ray. The number of these ganglia corresponds with that of the rays or arms; being *five* in the common Star-fish; and from *nine* to *fifteen*, in the species possessing those several numbers of members. The ganglia appear to be all similar to one another in function, as they are in the distribution of their branches; every one of them sending a large trunk along its own ray, and two small filaments to the organs in the central disk. The rays being all so similar in structure, as to be exact repetitions of each other, it would appear that none of the ganglia can have any controlling power over the rest. All the rays (in certain species) have at their extremities what seem to be very imperfect eyes; and so far as these can aid in directing the movements of the animal, it is obvious that they will do so towards all sides alike. Hence there is no one part, which corresponds to the *head* of higher animals; and the ganglia of the nervous system, like the parts they supply, are but repetitions of one another, and are capable of acting quite independently. Each would perform its own individual functions if separated from the rest; but, in the entire animal, their actions are all connected with others by the circular cord, which passes from every one of the five ganglia to those on either side of it. We shall find that, in Articulated and Vertebrated animals, there is a similar repetition of corresponding ganglia, on the two sides of the median plane of the body; and that these are connected by *transverse* bands, analogous in function to the circular cord of the Star-fish. Moreover, we shall see a like repetition of ganglia, almost or precisely similar in function, in passing from one extremity

of these animals to the other; and these ganglia are connected by longitudinal cords, whose function is in like manner *commissural.*—From the best judgment we can form of the actions of the Star-fish, by comparing them with the corresponding actions of higher animals, we may fairly regard the greater number of them as simply *reflex;* being performed in direct respondence to external stimuli, the impression made by which is propagated to one or more of the ganglia, and excites in them a motor impulse. How far the movements of these animals are indicative of *sensation*, we have not the power of determining; but it may be safely affirmed, that they afford very little indication, if any, of the exercise of reasoning faculties, or of voluntary power.

850. Perhaps the simplest form of a Nervous system is that presented by certain of the lower Mollusca; for here, the body not possessing any repetition of similar parts, the nervous system is destitute of that multiplication of ganglia which we see in the Star-fish; whilst the limited nature of the animal powers involves a corresponding simplicity in the integral parts of their instrument. The animals, to which reference is here made, form the class *Tunicata;* which is intermediate, in many respects, between the ordinary Mollusks and the Zoophytes. They consist essentially of an external membranous bag or tunic; within which is a muscular envelop; and within this, again, a respiratory sac, which may be considered as the dilated pharynx of the animal. At the bottom of this last, is the entrance to the stomach; which, with the other viscera, lies at the lower end of the muscular sac. The external envelops have two orifices; a mouth, to admit water into the pharyngeal sac; and an anal orifice, for the expulsion of the water which has served for respiration, and of that which has passed through the alimentary canal, together with the fecal matter, the ova, &c. A current of water is continually being drawn into the pharyngeal sac, by the action of the cilia that line it; and of this, a part is driven into the stomach, conveying to it the necessary supply of aliment in a very finely divided state; whilst a part is destined merely for the aëration of the circulating fluid, and is transmitted more directly to the anal orifice, after having served that purpose. These animals are for the most part fixed to one spot, during all but the earliest period of their existence; and they give but little external manifestation of life, beyond the continual entrance and exit of the currents already adverted to, which, being effected by ciliary action, is altogether independent of the nervous system (§ 224). When any substance is drawn in by the current, however, the entrance of which would be injurious, it excites a general contraction of the mantle or muscular envelop; and this causes a jet of water to issue from one or both orifices, which carries the offending body to a distance. And, in the same manner, if the exterior of the body be touched, the mantle suddenly and violently contracts, and expels the contents of the sac.

851. These are the only actions, so far as we know, which the

Nervous system of these animals is destined to perform. They do not exhibit the least trace of eyes, or of other organs of special sense; and the only parts that appear peculiarly sensitive, are the small tentacula or feelers, that guard the oral orifice. Between the two apertures in the mantle, we find a solitary ganglion, which receives branches from both orifices, and sends others over the muscular sac. This, so far as we know at present, constitutes the whole nervous system of the animal; and it is fully sufficient to account for the movements which have been described. For the impression produced by the contact of any hard substance with the tentacula, or with the general surface of the mantle, being conveyed by the *afferent* fibres of this ganglion, will excite in it a reflex motor impulse; which, being transmitted to the muscular fibres of the contractile sac, as well as to those circular bands that surround the orifices and act as *sphincters*, will produce the movements in question.

852. In the *Conchifera*, or Mollusks inhabiting bivalve shells, there are invariably two ganglia, having different functions. The larger of these (Plate II, Fig. 1, *c*), corresponding to the single ganglion of the Tunicata, is situated towards the posterior end of the body (that is, the end most distant from the mouth), in the neighbourhood of the posterior muscle that draws the valves together; and its branches are distributed to that muscle, to the mantle, to the gills (*d*, *d*), and to the siphons (*e*, *e*), by which the water is introduced and carried off. But we find another ganglion, or rather pair of ganglia (*a*, *a*), situated near the front of the body, either upon the œsophagus, or at its sides; these ganglia are connected with the very sensitive tentacula, which guard the mouth; and they may be regarded as presenting the first approach, both in position and functions, to the brain of higher animals. In the *Oyster*, and others of the lower Conchifera, which have no foot, these are the only principal ganglia; but in those having a foot,—which is a muscular tongue-like organ,—we find an additional ganglion (*b*) connected with it. This is the case in the *Solen*, or animal of the Razor-shell; whose foot is a very powerful boring-instrument, enabling it to penetrate deeply into the sand.—Here, then, we have three distinct kinds of ganglionic centres; every one of which may be doubled, or repeated on the two sides of the body. *First*, the *cephalic* ganglia, *a*, *a*, which are probably the sole instruments of *sensation* and of the *consensual* movements; as well as of whatever *voluntary* power the animal may possess: these are almost invariably double, being connected together by a transverse band, which arches over the œsophagus. *Second*, the *pedal* ganglion, *b*, which is usually single, in conformity with the single character of the organ it supplies; but in one very rare Bivalve Mollusk, the foot is double, and the pedal ganglion is double also. *Third*, the *respiratory* ganglion, *c*, which frequently presents a form that indicates a partial division into two halves, corresponding with the repetition of the organs it supplies on the two sides of the body. Besides these principal centres, we meet with numerous smaller ones upon the nervous cords, (*f*, *f*, and

g, *g*,) which proceed from them to the different parts of the general muscular envelop or mantle.

853. Now it will be observed, that the two cephalic ganglia *a*, *a*, are connected with the pedal ganglion *b*, by means of a pair of trunks proceeding from the former to the latter; and that they are, in like manner, separately connected with the respiratory or branchial ganglion, *c*. It is found, upon careful dissection, that these cords do not serve merely to bring the *ganglia* into relation; but that a part of them pass *through* the ganglion into the trunks proceeding from it. Thus of the nerves which supply the large fleshy foot, and which appear to proceed from the pedal ganglion *b*, a part are undoubtedly connected with that ganglion alone, coming into relation with its vesicular substance; but a part also pass on to the cephalic ganglia, by the connecting trunks,—so that *these*, rather than the pedal ganglion, constitute their centre. The same may be said of the nerves proceeding from the branchial ganglion: a portion of them having their centre in the vesicular matter of that ganglion; whilst another portion has no relation to it whatever (beyond that of proximity), but passes through or over it, to become connected with the cephalic ganglia. There is good reason to believe, that the *pedal* and *branchial* ganglia minister to the purely *reflex* actions of the organs they respectively supply; and that they would serve this purpose as well, if altogether cut off from connection with the cephalic ganglia: whilst the latter, being the instruments of the actions which are called forth by sensation (whether these be of a *consensual* or of a *voluntary* nature), exert a general control and direction over the movements of the animal.

854. It is difficult to make satisfactory experiments upon this subject in these animals; their movements being for the most part slow and feeble, and their nervous system not readily accessible; and our idea of the respective functions of their ganglia is chiefly founded upon the distribution of their nerves, and upon the analogous operations of the ganglia that correspond to them in other animals. In ascending through the series of the Mollusca, we find the Nervous system increasing in complexity, in accordance with the general organization of the body: the addition of new organs of special sensation, and of new parts to be moved by muscles, involving the addition of new ganglionic centres, whose functions are especially adapted to these purposes. But we find no other multiplication of *similar* centres, than a doubling on the two sides of the body; excepting in a few cases, where the organs they supply are correspondingly multiplied. We have a very characteristic example of this in the arms of the Cuttle-fish, which are furnished with great numbers of contractile suckers, every one possessing a ganglion of its own. Here we can trace very clearly the distinction between the *reflex* actions of each individual sucker, depending upon the powers of its own ganglion; and the consensual or voluntary movement, which results from its connection with the cephalic ganglia. The nervous trunk, which

proceeds to each arm, may be distinctly divided into two tracts; in one of which there is nothing but *fibrous* structure, forming a direct communication between the suckers and the cephalic ganglia; whilst in the other are contained the ganglia, which peculiarly appertain to the suckers, and which are connected with them by distinct filaments: so that each sucker has a separate relation with a ganglion of its own, whilst all are alike connected with the cephalic ganglia, and are placed under their control. We see the results of this arrangement, in the modes in which the contractile power of the suckers may be called into operation. When the animal embraces any substance with its arm (being directed to this action by its sight or other sensation) it can bring all the suckers simultaneously to bear upon it; evidently by a voluntary or instinctive impulse, transmitted along the motor cords, that proceed from the cephalic ganglia to the suckers. On the other hand, any individual sucker may be made to contract and attach itself, by placing a substance in contact with it alone; and this action will take place equally well, when the arm is separated from the body, or even in a small piece of the arm when recently severed from the rest,—thus proving that, when it is directly excited by an impression made upon itself, it is a *reflex* act, quite independent of the cephalic ganglia, not involving sensation, and taking place through the medium of its own ganglion alone.

855. In the *Molluscous* classes, generally speaking, the Nervous system bears but a small proportion to the whole mass of the body; and the part of it which ministers to the *general* movements of the fabric, is often small in proportion to those which serve some *special* purpose, such as the actions of respiration. This is what we should expect from the general inertness of their character, and from the small amount of muscular structure which they possess. On the other hand, in the *Articulated* classes, in which the locomotive apparatus is highly developed, and its actions of the most energetic kind, we find the Nervous system almost entirely subservient to this function. In its usual form, it consists of a chain of ganglia, connected by a double cord; commencing in the head, and passing backwards through the body (Plate II., Fig 2). The ganglia, though they usually appear single, are really double; being composed of two equal halves, sometimes closely united on the median line, but occasionally remaining separate, like the cephalic ganglia of the Solen (Fig. 1, *a*, *a*), and being united together by a transverse commissural trunk. In like manner, the longitudinal cord, though really double (as seen in the upper part of Fig. 2), often appears to be single, in consequence of the close approximation of its lateral halves (as in the lower part of Fig. 2). In general we find a ganglion in each segment; giving off nerves to the muscles of the legs, as in Insects, Centipedes, &c.; or to the muscles that move the rings of the body, where no extremities are developed, as in the leech, worm, &c. In the lower Vermiform (or worm-like) tribes, especially in the marine species, the number of segments is frequently very great, amounting even to several hundreds;

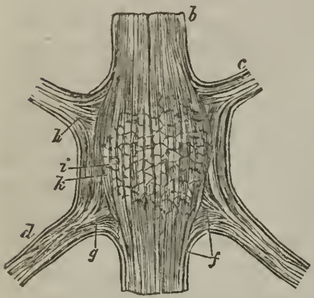
and the number of ganglia follows the same proportion. Whatever be their degree of multiplication, they seem but repetitions of one another; the functions of each segment being the same with those of the rest. The *cephalic* ganglia, however, are always larger and more important; they are connected with the organs of special sense; and they evidently possess a power of directing and controlling the movements of the entire body; whilst the power of each ganglion of the trunk is confined to its own segment.—The longitudinal ganglionic cord of Articulata occupies a position, which seems at first sight altogether different from that of the nervous system of Vertebrated animals; being found in the neighbourhood of the *ventral* or inferior surface of their bodies; instead of lying just beneath their dorsal or upper surface. There is reason, however, for regarding the *whole* of the body of these animals as having an inverted position; so that they may be considered as really crawling upon their backs. On this view, their longitudinal nervous tract corresponds with the spinal cord of Vertebrata in *position*, as we shall find that it does in *function*.

856. We shall draw our chief illustrations of the structure of the nervous system in the Articulated series, from the class of Insects; in which it has been particularly examined. In these animals, the number of segments never exceeds twelve (exclusive of the head), either in their larva, pupa, or imago states; and the total number of pairs of ganglia, therefore, never exceeds thirteen, including the cephalic ganglia. These, in the larva, are nearly equal in size, one to another (Plate II., Fig. 2, *a*, and 1—12); the functions of the different segments of the body being almost uniform; and the development of the organs of special sense not being such, as to involve any considerable predominance in the size of the cephalic ganglia. We observe, at the anterior extremity, the pair of cephalic ganglia (*a*); from which proceeds, on each side, a cord of communication to the first ganglion (1) of the trunk. This double cord, with the ganglia above and below, thus forms a ring, which embraces the œsophagus; the cephalic ganglia being situated on the upper side of it, whilst the ganglionic column of the trunk lies beneath the alimentary canal along its whole length. In the *Sphinx ligustri*, or Privit Hawk-moth, the nervous system of whose larva is here represented, the last two segments of the body are drawn together, as it were, into one; and instead of distinct 11th and 12th ganglia, we find but a single mass, nearly double the size of the rest, and obviously formed of the elements that would have otherwise gone to form the two.

857. When the structure of the chain of ganglia is more particularly inquired into, it is found to consist of two distinct *tracts;* one of which is composed of nervous fibres only, and passes backwards from the cephalic ganglia, over the surface of all the ganglia of the trunk, giving off branches to the nerves that proceed from them; whilst the other includes the ganglia themselves. Hence, as in the Mollusca, every part of the body has two sets of nervous connections; one with the cephalic ganglia; and the other with the ganglion of its own seg-

ment. Impressions made upon the afferent fibres, which proceed from any part of the body to the cephalic ganglia, become *sensations* when conveyed to the latter; whilst, in respondence to these, the influence of the *instincts*, or of the *will*, operating through the cephalic ganglia, harmonizes and directs the general movements of the body, by means of the efferent nerves proceeding from them. For the *reflex* operations, on the other hand, the ganglia of the ventral cord are sufficient; each one ministering to the actions of its own segment, and, to a certain extent also, to those of other segments. It has been ascertained by the careful dissections of Mr. Newport, that of the fibres constituting the roots, by which the nerves are implanted in the ganglia, some pass into the vesicular matter of the ganglion, and, after coming into relation with its vesicular substance, pass out again on the same side (Fig. 141, *f*, *k*); whilst a second set, after traversing the vesicular matter, passes out by the trunks proceeding from the opposite side of the same ganglion; and a third set runs along the portion of the cord which connects the ganglia of different segments, and enters the nervous trunks that issue from them, at a distance of one or more ganglia above or below. Thus it appears, that an impression conveyed by an afferent fibre to any ganglion, may excite a motion in the muscles of the same side of its own segment; or in those of the opposite side; or in those of segments at a greater or less distance, according to the point at which the efferent fibres leave the cord.

Fig. 141.



Portion of the ganglionic tract of *Polydesmus maculatus*;—*b*, inter-ganglionic cord; *c*, anterior nerves; *d*, posterior nerves; *f*, *k*, fibres of reflex action; *g*, *h*, commissural fibres; *i*, longitudinal fibres, softened and enlarged, as they pass through ganglionic matter.

858. The general conformation of Articulated animals, and the arrangement of the parts of their nervous system, render them peculiarly favourable subjects for the study of the *reflex* actions; some of the principal phenomena of which will now be described. If the head of a Centipede be cut off, whilst it is in motion, the body will continue to move onwards by the action of the legs; and the same will take place in the separate parts, if the body be divided into several distinct portions. After these actions have come to an end, they may be excited again by irritating any part of the nervous centres, or the cut extremity of the nervous cord. The body is moved forwards by the regular and successive action of the legs, as in the natural state; but its movements are always forwards, never backwards, and are only directed to one side, when the forward movement is checked by an interposed obstacle. Hence, although they might *seem* to indicate consciousness and a guiding will, they do not so in reality; for they are carried on, as it were, mechanically: and show no direction of object, no avoidance of danger. If the body be opposed in its progress

by an obstacle of not more than half its own height, it mounts over it, and moves directly onwards, as in its natural state; but if the obstacle be equal to its own height, its progress is arrested, and the cut extremity of the body remains forced up against the opposing substance,—*the legs still continuing to move.*—If, again, the nervous cord of a Centipede be divided in the middle of the trunk, so that the hinder legs are cut off from connection with the cephalic ganglia, they will continue to move, but not in harmony with those of the fore part of the body; being completely paralyzed, as far as the animal's controlling power is concerned; though still capable of performing reflex movements, by the influence of their own ganglia, which may thus continue to propel the body, in opposition to the determination of the animal itself.—The case is still more remarkable, when the nervous cord is not merely divided, but a portion of it is entirely removed from the middle of the trunk; for the anterior legs still remain obedient to the animal's control; the legs of the segments, from which the nervous cord has been removed, are altogether motionless; whilst those of the posterior segments continue to act, through the reflex powers of their own ganglia, in a manner which shows that the animal has no power of checking or directing them.

859. The stimulus to the reflex movements of the legs, in the foregoing cases, appears to be given by the contact of the extremities with the solid surface on which they rest. In other cases, the appropriate impression can only be made by the contact of liquid; thus a Dytiscus (a kind of water-beetle), having had its cephalic ganglia removed, remained motionless, so long as it rested upon a dry surface; but when cast into water, it executed the usual swimming motions with great energy and rapidity, striking all its comrades to one side by its violence, and persisting in these for more than half an hour. Other movements, again, may be excited through the respiratory surface. Thus, if the head of a Centipede be cut off, and while it remains at rest, some irritating vapour (such as that of ammonia or muriatic acid) be caused to enter the air tubes on one side of the trunk, the body will be immediately bent in the opposite direction, so as to withdraw itself as much as possible from the influence of the vapour; if the same irritation be then applied on the other side, the reverse movement will take place; and the body may be caused to bend in two or three different curves, by bringing the irritating vapour into the neighbourhood of different parts of either side. This movement is evidently a reflex one, and serves to withdraw the entrances of the air-tubes from the source of irritation; in the same manner as the acts of coughing and sneezing in the higher animals cause the expulsion, from the air-passages, of solid, liquid or gaseous irritating matters, which may have found their way into them.

860. From these and similar facts it appears, that the ordinary movements of the legs and wings of Articulated animals are of a reflex nature, and may be effected solely through the ganglia with which these organs are severally connected; whilst in the perfect being, they

are harmonized, controlled, and directed by its instinct or its will, which act through the cephalic ganglia and the nerves proceeding from them. There is strong reason to believe, that the operations to which these ganglia are subservient, are almost entirely of a *consensual* nature; being immediately prompted by sensations, chiefly those of sight, and seldom involving any processes of a truly rational character. When we attentively consider the habits of these animals, we find that their actions, though evidently directed to the attainment of certain ends, are very far from being of the same spontaneous nature, or from possessing the same *designed* adaptation of means to ends, as those performed by ourselves, or by the more intelligent Vertebrata, under like circumstances. We judge of this by their unvarying character,—the different individuals of the same species executing precisely the same movements, when the circumstances are the same; and by the very elaborate nature of the mental operations, which would be required, in many instances, to arrive at the same results by an effort of reason. Of such we cannot have a more remarkable example, than is to be found in the operations of Bees, Wasps, and other social Insects; which construct habitations for themselves, upon a plan which the most enlightened human intelligence, working according to the most refined geometrical principles, could not surpass; but which yet do so without education communicated by their parents, or progressive attempts of their own, and with no trace of hesitation, confusion, or interruption,—the different individuals of a community all labouring effectively for one common purpose, because their instinctive or consensual impulses are the same.

861. It is interesting to remark that, in the change from the Larva to the perfect or Imago state of the Insect, the Cephalic ganglia undergo a great increase in size. (Plate II., Fig. 3, *a*, *a*.) This evidently has reference to the increased development of the organs of special sense in the latter; the eyes being much more perfectly formed; antennæ and other appendages used for feeling being evolved; and rudimentary organs of hearing and smell being added. In respondence to the new sensations, which the animal will thus acquire, a great number of new instinctive actions are manifested; indeed, it may be said, that the instincts of the perfect Insect have frequently nothing in common with those of the Larva. The latter have reference to the acquirement of food; the former chiefly relate to the acts of reproduction, and to the provisions requisite for the deposit and protection of the eggs and the early nutrition of the young.—We find another important change in the nervous system of the adult or perfect Insect; namely, the concentration of the ganglionic matter of the ventral cord in the thoracic region (*e*, *f*); with the three segments of which, the three pairs of legs and the two pairs of wings are connected. The nine segments of the abdomen, in the perfect Insect, give attachment to no organs of motion, and are seldom themselves very movable; and we find that the ganglia which correspond with them have undergone no increase in size, but have rather diminished, and have sometimes

almost completely disappeared. Where the last segment, however, is furnished with a particularly movable appendage, such as a sting, or an ovipositor, we always find a large ganglion in connection with it.

862. These ganglia of the ventral cord evidently correspond in function with the *pedal* ganglion of the Mollusca; being so many repetitions of it; in accordance with the number of members. We have now to speak of a system of *respiratory* ganglia, which also are repeated in like manner, in accordance with the condition of the respiratory apparatus; this being diffused through the whole body, in most of the Articulata, instead of being restricted to one spot as in the Mollusca. The system of respiratory nerves consists of a chain of minute ganglia, lying upon the larger cord, and sending off its delicate nerves between those that proceed from the ganglia of the latter, as seen in Fig. 2. These respiratory ganglia and their nerves are best seen in the thoracic portion of the cord, where the cords of communication between the pedal ganglia diverge or separate from one another. And this is particularly the case in the Pupa state, when the whole cord is being shortened, and their divergence is increased. The thoracic portion of the cord, in the Pupa of the Sphinx ligustri, is shown in Plate II., Fig. 4; where *a*, *b*, and *c*, represent the 2d, 3d, and 4th double ganglia of the ventral cord; *d*, *d*, the cords of connection between them, here widely diverging laterally; and *e*, *e*, the small respiratory ganglia, which are connected with each other by delicate filaments that pass over the ganglia of the ventral cord, and which send off lateral branches, that are distributed to the air-tubes and other parts of the respiratory apparatus, and communicate with those of the other system.

863. Besides the Respiratory system of ganglia and nerves, there is in Insects, as in some Mollusks, a set of minute ganglia, which is especially connected with the acts of mastication and swallowing, its filaments being distributed to the muscles of the mouth and pharynx, and some of its ganglia being even found on the stomach, where that organ is remarkable for its muscular powers. The number and arrangement of these ganglia vary considerably in different animals, even in those of the same group; but some traces of this distinct system, which is designated as the *stomato-gastric*, may always be found. One of the minute ganglia appertaining to it, and forming its anterior termination, is seen to lie on the median line, in front of the great cephalic ganglia, in Plate II., Fig. 3, *c*. From this a trunk passes backwards along the œsophagus; which may be likened to the œsophageal branches of the Par vagum in Vertebrata. Two other small ganglia, communicating with this, are seen at *d*, *d*.

864. We are not without traces, moreover, among Invertebrated animals, of the *Sympathetic* system of the higher classes; though it is quite a mistake to compare the *entire* system of nerves and ganglia in the former, with the Sympathetic system of the latter,—as was formerly done. The chief distribution of the branches of the Sympa-

thetic of Vertebrata is upon the walls of the blood-vessels, and upon the muscular substance of the heart and alimentary canal; and it is by the passage of some of the filaments, from the system of minute ganglia just pointed out, to the dorsal vessel, that we recognize it as combining the functions of the Sympathetic with those of the gastric and cardiac portions of the Par vagum. It will be remembered that there is a frequent inosculation between these two nerves, even in the highest animals.

865. Thus we have seen that, in Invertebrated animals, the Nervous System consists of a series of isolated ganglia, connected together by fibrous trunks. The number of these ganglia, and the variety of their function, entirely depend upon the number and variety of the organs to be supplied. In the lowest Mollusca, the regulation of the ingress and egress of water seems almost the only function to be performed; and here we have but a single ganglion. In the Star-fish, we have five or more ganglia; but they are all repetitions, one of another. In the higher Mollusca, and in Articulata, we have a ganglion, or more commonly a pair of ganglia, situated at the anterior extremity of the body, connected with the organs of special sensation, and evidently exerting a dominant influence over the rest. In the lower Mollusca, we have but a single ganglion for general locomotion; but this is doubled laterally, and repeated longitudinally in the Articulata, in accordance with the multiplication of their locomotive organs, so as to form the ventral cord. In like manner, the Mollusca possess a single ganglionic centre for the respiratory movements; and this is repeated in every segment of the Articulata, forming a chain of respiratory ganglia, which regulates the actions of the extensively-diffused respiratory apparatus of these animals. The acts of mastication and deglutition, again, in both sub-kingdoms, are under the control of a distinct set of ganglionic centres; which are connected, however, like the preceding, with the cephalic ganglia; and it is probable that, as in other cases, some filaments from the latter enter into all the branches, which they transmit to the muscles. And we have further seen, that, wherever special organs are developed, whose operations depend upon muscular contraction, ganglionic centres are developed in immediate relation with them; so as to enable them to act by their simple reflex power, as well as under the direction of the cephalic ganglia;—as in the case of the suckers of the Cuttle-fish.

866. When we direct our attention to the Nervous system of the Vertebrated series, we perceive that it differs from that of the Invertebrated classes we have been considering in two remarkable features. In these last, it has seemed but as a mere appendage to the rest of the system, designed to bring its several parts into more advantageous relation. On the other hand, in the Vertebrata, the whole structure appears subservient to it, and designed but to carry its purposes into operation. Again, in the Invertebrata, we do not find any special adaptation of the organs of support for the protection of the Nervous System. It is either enclosed, with the other soft parts of

the body, in one general hard tegument, as in the Star-fish and other Echinodermata, and in Insects, Crustacea, and other Articulata; or it receives a still more imperfect protection, or even none at all, as in the Mollusca. Now in the Vertebrata, we find a special and complex bony apparatus, adapted in the most perfect manner for the protection of the Nervous system; and it is, in fact, the possession of a jointed spinal column, and of its cranial expansion, which best characterizes the group.

867. The Nervous System of Vertebrata is not merely remarkable for its high development, relatively to the remainder of the structure. It is also distinguished by the possession of parts, to which we have nothing analogous in the lower tribes; and by the mode in which these are concentrated and combined, so as to form one continuous mass, instead of consisting of a series of scattered ganglia.—The chief parts which are newly introduced (so to speak) in this subkingdom, are the Cerebral Hemispheres and Cerebellum; of which there are no traces whatever in the lower Articulata and Mollusca, and but very minute representations in the highest. These are superimposed, as it were, upon the cephalic ganglia connected with the organs of special sense, and upon the cords that connect them with the first ganglion of the trunk.—Again we find that the locomotive ganglia, which formed the long-knotted cord of the Articulata, are united with the centres of the respiratory system, and with those of the stomato-gastric system; to form one continuous tract, which commences anteriorly from the ganglia of special sense, and runs backwards* without interruption, in the canal of the Vertebral column, forming the Spinal Cord. This is a *continuous* instead of an *interrupted* ganglionic mass; it is composed of two lateral halves, precisely similar to each other; and each of these consists of two parts, as distinct from each other as the two tracts in the ventral cord of the Articulata,—namely, a *fibrous* structure, which is continuous between the Encephalon (or collection of nervous masses within the cranium) and certain fibres of the roots of the spinal nerves, and which also serves to connect together the different parts of the cord itself,—and a *vesicular* portion, which forms the proper centre of another set of fibres entering into the roots of those nerves. The anterior portion of the Spinal cord, which is prolonged into the cranium, and comes into immediate relation with the encephalon, is termed the *Medulla Oblongata.* It is in this that the centres of the respiratory and stomato-gastric nerves are found; the situation of these important ganglia within the cranium, being obviously destined to protect them from those injuries to which the Spinal Cord itself is liable.

868. Thus, then, we recognize in the Nervous system of Vertebrata the following fundamental parts.—1. A system of ganglia subservient to the reflex actions of the organs of *locomotion*, and corresponding

* When we speak of the Vertebrata generally, their bodies are of course supposed to be in a horizontal position,—not vertical as in Man.

with the chain of pedal or locomotive ganglia that makes up the chief part of the ventral cord of the Articulata; in this system, the gray or vesicular matter forms one continuous tract, which occupies the interior of the *Spinal Cord.*—2. A ganglionic centre for the movements of *respiration*, and another for those of *mastication* and *deglutition;* these, with part of the preceding, make up the proper substance of the *Medulla Oblongata.*—3. A series of ganglia, in immediate connection with the organs of *Special Sense;* these are situated within the cranium, at the anterior extremity of the Medulla Oblongata; and, in the lowest Vertebrata, they constitute by far the largest portion of the entire Encephalon.—4. The *Cerebellum*, which is a sort of off-shot from the upper extremity of the Medulla Oblongata, lying behind the preceding.—5. The *Cerebral Hemispheres*, a pair of ganglionic masses, which lie upon the ganglia of special sense, capping them over more or less completely, according to their relative development.—These two last organs exist in the lowest Vertebrata, as in Invertebrated animals generally, in quite a rudimentary state; but their development, relatively to other parts of the Encephalon, and to the entire bulk of the animal, increases as we ascend the scale; so that in Man and the higher Mammalia they constitute by far the largest portion of the Nervous centres, and are essential to the greater part of the operations of the Nervous system. The development of the *Cerebral* Hemispheres holds a close relation with the increase of the *Intelligence*, and with the predominance of the *Will* over the involuntary impulses. The increased size of the Cerebellum, on the other hand, seems connected with the necessity which exists, for the adjustment and combination of the locomotive powers, when the variety in the movements performed by the animal is great, and a more perfect harmony is required among them.—A sketch of the mode in which these different parts are combined and arranged in the several classes of Vertebrata, and of their relative development in each, will aid us in the subsequent more detailed examination of their functions.

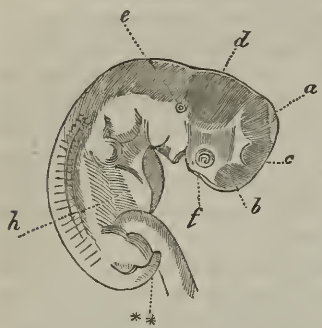
869. In the class of *Fishes*, taken as a whole, the Encephalon bears a much smaller proportion to the Spinal Cord, than in the higher Vertebrata. In the curious *Amphioxus*, or Lancelot, there is no discoverable nervous mass anterior to the Medulla Oblongata; and we have here, therefore, an animal regularly formed upon the plan, which occasionally presents itself as a monstrosity in Man, namely, having the Spinal Cord and Medulla Oblongata for the whole of the nervous centres, and being *anencephalous*, or destitute of any proper encephalon. In some of the lowest Vermiform (worm-like) Fishes, such as the Lamprey, the cephalic masses are very little more developed in proportion to the Spinal Cord, than are the cephalic ganglia of Insects in reference to their chain of ventral ganglia. But as the organs of special sense acquire a more complete evolution, we find the ganglia connected with them presenting a greatly-increased size. On opening the cranial cavity of a Fish, we usually observe four

nervous masses (three of them in pairs) lying, one in front of the other, nearly in the same line with the Spinal cord. The first or most anterior of these are the Olfactory ganglia (Plate II., Figs. 5, 6, 7, *a*), or the ganglia of the nerves of smell; the nature of which is known, from their being situated at the origin of the Olfactory nerves. In the Shark and some other Fishes, these are separated from the rest by peduncles or foot-stalks; a fact of much interest, as explaining the arrangement which we find in Man. What is commonly termed the *trunk* of *his* Olfactive nerve is really the commissure connecting the Olfactive ganglion,—known as the bulbous enlargement that lies upon the cribriform plate of the Ethmoid bone,—with the other portions of his Encephalon; the proper fibres of the nerve being those, which come off from this ganglion, in the numerous branches that proceed from it into the nasal cavity.—Behind the Olfactive ganglia is a pair of masses, *b*, *b*, of which the relative size varies greatly in different Fishes. Thus in the Perch, whose Encephalon is here figured, their size is intermediate between that of the first and third pairs; being as much inferior to that of the third, as it is superior to that of the first. On the other hand, in the Shark and several other Fishes, they are considerably larger than the succeeding pair. These second ganglia are the Cerebral Hemispheres.—Behind them, and forming the third pair of ganglionic masses, *c*, *c*, are two large bodies, from which the optic nerves arise; these are evidently the Optic ganglia, corresponding to the principal mass of the cephalic ganglia in Insects, and the higher Mollusca.—And at the back of these, overlying the top of the spinal cord, is a single mass, *d*, the Cerebellum. This, also, varies greatly in its relative dimensions; being much more highly developed in the Active and rapacious Sharks, than it is in Fishes of inferior muscular energy and variety of movement.—The Spinal Cord *e*, is divided at the top by a fissure, which is most wide and deep beneath the cerebellum, where there is a complete separation between its two halves. This opening corresponds to that, through which the œsophagus passes in the Invertebrata; but as the entire nervous mass of Vertebrated animals lies above the alimentary canal (or nearer the dorsal surface), it does not serve the same purpose in them; and in the higher classes, the fissure is almost entirely closed by the union of the two halves on the median plane,—the *fourth* ventricle, however, being a remnant of it. This cavity is partly seen in Fig. 7, which is a vertical section of the brain whose upper and under surfaces are shown in Figs. 5 and 6.

870. The Optic lobes of Fishes must not be confounded with the Thalami optici of the higher Vertebrata, with which they have only a slight analogy, as is proved by their position and connections. They are rather to be compared with the Corpora Quadrigemina, which are the real ganglia of the optic nerve. Their analogy is not so complete, however, to these bodies in their fully-formed brain of the higher Vertebrata; as to the certain parts which occupy their place at an earlier period. In the Human embryo, at about the 6th week, the

Encephalon consists of a series of vesicles arranged in a line with each other; of which those that represent the cerebrum (*b*, Fig. 142) are the smallest, whilst that which represents the cerebellum (*d*) is the largest. Between the cerebral and cerebellic vesicles, are *two* others, (*c*, and *a*), of which the posterior one is the Optic ganglion, and answers to the Tubercula quadrigemina; whilst the anterior contains the third ventricle, and corresponds in some degree to the thalami optici. This condition is precisely represented in the Lamprey; but in most Fishes, the Optic ganglia, and the parts surrounding the third ventricle, form but one lobe; so that the third ventricle seems hollowed out of the optic ganglia, as shown in Fig. 7, *c* (Plate II.).—Besides the Olfactive and Optic ganglia, there are in many Fishes distinct *Auditory* ganglia, from which the nerves that minister to the sense of hearing originate; these are frequently blended, however, with the Medulla oblongata, their vesicular substance forming a part of its gray matter.—It is curious to notice the very large comparative size of the Pineal gland (*f*), and of the Pituitary body (*h*), in this class; the functions of these organs are entirely unknown.

Fig. 142.



Human embryo of sixth week, enlarged about three times:—*a*, vesicle of corpora quadrigemina; *b*, vesicle of cerebral hemispheres; *c*, vesicle of thalami optici and third ventricle; *d*, vesicle for cerebellum and medulla oblongata; *e*, auditory vesicle; *f*, olfactory fossa; *h*, liver; ** caudal extremity.

871. The Encephalon of *Reptiles* does not show any considerable advance in its general structure, above that of the higher Fishes. The Cerebral Hemispheres (Figs. 8, 9, 10, *b*) are always much larger than the Olfactive and Optic ganglia; and they generally cover in the latter (*c*, *e*) in part, by their posterior extremities. The Cerebellum is almost invariably of small proportional dimensions; and this is especially the case in the Frog, in which it does not even cover in the fourth ventricle. This low development of the Cerebellum in Reptiles, is what might be anticipated from the general inertness of these animals, and the want of variety in their movements. The Spinal Cord is still very large, in proportion to the nervous masses contained in the skull; and, as we shall hereafter see, its power of keeping up the movements of the body, after it has been cut off from all connection with the brain, is very considerable.—We find that, in Reptiles, as in Fishes, the Spinal Cord may have a nearly uniform size from one extremity to the other, like the ventral cord of the lower Articulata; or it may present considerable enlargements at particular spots, like the ganglionic cord in the thoracic region of Insects. This difference depends upon the degree of development of the special locomotive organs. Thus in the Eel and Serpent, whose movements are accomplished by the undulations of the entire trunk, and which are

destitute of members, we find an uniform development of ganglionic matter in the spinal cord. On the other hand, in the Flying-fish, in which the pectoral fins or anterior extremities effect the greater part of the propulsion of the body, we find a great ganglionic enlargement of the Spinal cord, at the part with which the nerves of those members are connected: in the Frog, whose movements are chiefly effected by the posterior extremities, we find a similar enlargement at the roots of the crural nerves; and in the Turtles and Lizards, the two pairs of whose members are nearly equal in function, and serve to effect the principal movements of the body, we find an anterior and posterior enlargement of the Spinal Cord, corresponding to the parts with which the nerves of these members are connected.

872. We find in *Birds* a considerable advance in the character of the Encephalon, towards that which it presents in Mammalia. The Cerebral Hemispheres (Plate II., Figs. 11, 12, 13, *b*) are greatly increased in size; and then cover in, not merely the olfactory ganglia, but in great part also the optic ganglia. The former are of comparatively small size; the organ of smell in Birds not being much developed. The latter are very large, in conformity with the acuteness of sight, which is highly characteristic of the class. The Cerebellum is of large size, as we should expect from the number and complexity of the muscular movements performed by animals of this class; but it is still undivided into hemispheres. The Spinal Cord is still of considerable size in comparison with the Encephalon; and it is much enlarged at the points whence the legs and wings originate. In the species which have the most energetic flight, such as the Swallow, the enlargement is the greatest where the nerves of the wings come off; but in those which, like the Ostrich, move principally by running on the ground, the posterior enlargement, from which the legs are supplied with nerves, is much the more considerable.

873. In the *Mammalia* we find the size and general development of the Encephalon presenting a gradual increase, as we ascend the series, from the non-placental Monotremes and Marsupials, towards Man. In the former, the Hemispheres exhibit no convolutions; and the great transverse commissure, or connecting band of fibrous structure,—termed the corpus callosum,—is deficient. As we rise through the true viviparous division of the class, we notice a gradually increasing prolongation of the Cerebral Hemispheres backwards; so that first the optic ganglia, and then the cerebellum, are covered in by them. The latter partly shows itself, however, in all but Man and the Quadrumana, when we look at the brain from above downwards; as we see in the Encephalon of the Sheep (Plate II., Figs. 14, 15, *d*). The Cerebral hemispheres increase, not only in size, but also in complexity of structure, both external and internal. Their exterior, instead of remaining smooth, is marked by convolutions; which serve to extend very greatly the amount of surface, over which blood-vessels can pass into the gray substance. Their internal structure becomes more complex, in the same proportion as their size and the

depth of their convolutions increase; and in Man all these conditions present themselves in a far higher degree than in any other animal. The number of commissural bands, connecting the two hemispheres with each other transversely, and uniting their anterior and posterior portions, is very greatly increased; and, in fact, a large proportion of their mass is composed, in Man and the higher Mammalia, of fibres of this character. In proportion to the increase of the Cerebral hemispheres, there is a diminution in the size of the ganglia of special sense; and this is seen when we compare them, not merely with the rest of the Encephalon, but even with the Spinal Cord. The Olfactive ganglia (Fig. 14, *a*), are always readily discoverable; being separated from the remainder of the encephalic masses by a peduncle on each side. The Optic ganglia, (Fig. 15, *c*,) on the other hand, are so completely covered in by the Hemispheres, that it is only when the latter are turned aside that we can discern them. They differ in external aspect from the optic ganglia of Birds and the lower Vertebrata; being divided by a transverse furrow into anterior and posterior eminences,—whence they are known as the Corpora Quadrigemina. The Cerebellum is chiefly remarkable for the development of its lateral parts or hemispheres, and for the intricate arrangement of the gray and white matter in them (Fig. 15, *d*); the central portion, sometimes called the vermiform process, is relatively less developed than in the lower Vertebrata, where it forms the entire organ. The Spinal Cord is much reduced in size, when compared with other parts of the nervous centres; the motions of the animal, in this class, being more dependent upon its will, or guided by its sensations; and the simply reflex actions bearing a much smaller proportion to the rest. The development of ganglionic enlargements, in accordance with the presence or absence of high locomotive powers in the extremities, follows the same rule as in the preceding classes.

3. *Functions of the Spinal Cord and its Nerves.*

874. In commencing our more detailed examination into the functions of the different parts of the Nervous system in Vertebrated animals, it seems best to commence with the Spinal Cord; this being the portion whose presence is most essential to the continuance of life. As already mentioned, Infants are sometimes born without any Cerebrum or Cerebellum; and such have existed for several hours or even days, breathing, crying, sucking, and performing various other movements. The Cerebrum and Cerebellum have been experimentally removed from Birds and young Mammalia, thus reducing these beings to a similar condition; and all their vital operations have, nevertheless, been so regularly performed, as to enable them to live for weeks, or even months. In the Amphioxus, as already remarked, we have an example of a completely-formed adult animal; in which no rudiment of a Cerebrum or Cerebellum can be detected. And in ordinary profound sleep, or in apoplexy, the functions of these or-

gans are so completely suspended, that the animal is, in all essential particulars, in the same condition for a time as if destitute of them. It is possible, indeed, to reduce a Vertebrated animal to the condition (so far as its nervous system is concerned) of an Ascidian Mollusk (§ 850); for it may continue to exist for some time, when not merely the Cerebum and Cerebellum have been removed from above, but when nearly the whole Spinal Cord has been removed from below, —that part only of the latter being left, which is the centre of the respiratory actions, and which corresponds to the single ganglion of the Tunicata. On the other hand, no animal can exist by its Encephalon alone, the Spinal Cord being destroyed or removed; for the reflex actions of the latter are so essential to the continuance of its respiration, and consequently of its circulation, that if they be suspended (by the destruction of the portion of the cord which is concerned in them), all the organic functions must soon cease.

875. Although the Spinal Cord was formerly regarded as little else than a bundle of nerves proceeding from the Brain, yet its true rank, as a distinct centre of nervous action, is now universally admitted. That the actions performed by it are of a purely *reflex* nature,—consisting in the excitement of muscular movements, in respondence to external impressions, without the necessary intervention of sensation, —appears to be a necessary inference, from the facts that have been brought to light by experiment and observation. Experiments on the nature of this function are best made upon cold-blooded animals; as their general functions are less disturbed by the effects of severe injuries of the nervous system, than those of Birds and Mammals. When the Cerebrum has been removed, or its functions have been suspended by a severe blow upon the head, a variety of motions may be excited by their appropriate stimuli. Thus, if the edge of the eyelid be touched with a straw, the lid immediately closes. If a candle be brought near the eye, the pupil contracts. If liquid be poured into the mouth, or a solid substance be pushed within the grasp of the muscles of deglutition, it is swallowed. If the foot be pinched, or burned with a lighted taper, it is withdrawn; and (if the animal experimented on be a Frog) the animal will leap away, as if to escape from the source of irritation. If the cloaca be irritated with a probe, the hind legs will endeavour to push it away.

876. Now the performance of these, as well as of other movements, many of them most remarkably adapted to an evident purpose, might be supposed to indicate, that *sensations* are called up by the impressions; and that the animal can not only *feel*, but can *voluntarily* direct its movements, so as to get rid of the irritation which annoys it. But such an inference would be inconsistent with other facts.—In the first place, the motions performed by an animal under such circumstances are never spontaneous, but are always excited by a *stimulus* of some kind. Thus, a decapiated Frog, after the first violent convulsive movements occasioned by the operation have passed away, remains at rest until it is touched; and then the leg, or its

whole body, may be thrown into sudden action, which immediately subsides again. In the same manner, the act of swallowing is not performed, except when it is excited by the contact of food or liquor; and even the respiratory movements, spontaneous as they seem to be, would not continue, unless they were continually re-excited by the presence of venous blood in the vessels. These movements are all *necessarily* linked with the stimulus that excites them;—that is, the same stimulus will always produce the same movement, when the condition of the body is the same. Hence it is evident, that the judgment and will are not concerned in producing them; and that the *adaptiveness* of the movements is no proof of the existence of consciousness and discrimination in the being that executes them,—the adaptation being made *for* the being, by the peculiar structure of its nervous apparatus, which causes a certain movement to be executed in respondence to a given impression,—not *by* it. An animal thus circumstanced may be not unaptly compared to an automaton; in which particular movements adapted to produce a given effect, are produced by touching certain springs. Here the adaptation was in the mind of the maker or designer of the automaton; and so it evidently is, in regard to the reflex or consensual movements of animals, as well as with respect to the various operations of their nutritive system, over which they have no control, yet which concur most admirably to a common end.

877. Again, we find that such movements may be performed, not only when the Brain has been removed, the spinal cord remaining entire, but also when the Spinal cord has been itself cut across, so as to be divided into two or more portions,—each of them completely isolated from each other, and from other parts of the nervous centres. Thus, if the head of a Frog be cut off, and its spinal cord be divided in the middle of the back, so that its fore legs remain connected with the upper part, and its hind legs with the lower, each pair of members may be excited to movement by a stimulus applied to itself; but the two pairs will not exhibit any consentaneous motions, as they will do when the spinal cord is undivided. Or, if the Spinal cord be cut across, without the removal of the Brain, the lower limbs may be *excited* to movement, by an appropriate stimulus, though they are completely paralyzed to the *will;* whilst the upper remain under the control of the animal, as completely as before. Now it is not conceivable that, in this last case, sensation and volition should exist in that portion of the spinal cord which remains connected with the nerves of the posterior extremities, but which is cut off from the brain. For, if it were so, there must be two distinct centres in the same animal, the attributes of the brain not being affected; and, by dividing the spinal cord into two or more segments, we might thus create in the body of one animal two or more distinct centres of sensation, independent of that which still holds its proper place in the Encephalon. To say that two or more distinct centres of sensation are present in such a case, would really be in effect the same as saying, that

there are two or more distinct *minds* in one body,—which is manifestly absurd.

878. But the best proofs of the limitation of the endowments of the Spinal Cord, are derived from the phenomena presented by the Human subject, in cases where that organ has suffered injury, by disease or accident, in the middle of the back. We find that, when this injury has been severe enough to produce the effect of a complete division of the Cord, there is not only a total want of voluntary control over the lower extremities, but a complete absence of sensation also,—the individual not being in the least conscious of any impression made upon them. When the lower segment of the Cord remains sound, and its nervous connections with the limbs are unimpaired, distinct reflex movements may be excited in the limbs by stimuli, directly applied to them,—as, for instance, by pinching the skin, tickling the sole of the foot, or applying a hot plate to its surface;—and this without the least sensation, on the part of the patient, either of the cause of the movement, or of the movement itself. This fact, taken in connection with the preceding experiments, both upon Vertebrated and Articulated animals, distinctly proves that Sensation is *not* a necessary link in the chain of reflex actions; but that all which is required is an *afferent* fibre, capable of receiving the impression made upon the surface, and of conveying it to the centre; a *ganglionic centre*, composed of vesicular nervous substance, into which the afferent fibre passes; and an *efferent* fibre, capable of transmitting the motor impulse, from the ganglionic centre, to the muscle which is to be thrown into contraction.

879. These conditions are realized in the Spinal Cord. We may have reflex actions excited through any one isolated segment of it, as through a single ganglion of the ventral cord of Articulata; but they are then confined to the parts supplied by the nerves of that segment. Thus, if the spinal cord of a Frog be divided just above the origin of the crural nerves, the hind-legs may be thrown into reflex contraction by various stimuli applied to themselves; but the fore legs will exhibit no movement of this kind. But when the brain has been removed, and the Spinal Cord is left entire, movements may be excited in distant parts,—as, for example, in the fore legs, by any powerful irritation of the posterior extremities,—and vice versâ. This is particularly well seen in the convulsive movements, which take place in certain disordered states of the nervous system; a slight local irritation being sufficient to throw almost any muscles of the body into a state of energetic action (§ 885). And a similar state may be artificially induced, by applying Stryclinine (in solution) to the Spinal Cord of a decapitated Frog.

880. The minute Anatomy of the Spinal Cord is a subject of great difficulty; and our notions of the course of the fibres within it are rather founded upon physiological phenomena, and upon the more evident structure of the ventral column in Articulata, than upon what can be clearly demonstrated in Vertebrated animals. The *roots* of

the Spinal nerves are all distinctly separable into an interior and a posterior fasciculus; and it is certain that these fasciculi have entirely opposite functions. If they be laid bare, and the anterior fasciculus of any spinal nerve be touched, violent contractions are immediately seen in the muscles supplied by that nerve; these contractions are as strongly manifested, if the anterior roots be be divided, and their separated ends be irritated; whilst no such result follows, whatever amount of irritation be applied to the ends still in connection with the cord. Notwithstanding these violent movements, the animal shows little or no sign of pain.—On the other hand, if the posterior roots be irritated, the animal gives signs of acute pain, and no vigorous muscular contractions are produced. The movements which are witnessed are evidently of a *reflex* nature, being called forth through the anterior roots; as is proved by their cessation when these are divided. Further, if the posterior roots be divided, and the separated ends be irritated, no effect whatever is produced; no movement is excited; and no sensation is occasioned; but if the ends still in connection with the cord be irritated, the animal shows signs of pain as before.—Hence it is evident, that the *posterior* roots are made up of *afferent* fibres; that is, of the fibres which convey impressions *towards* the nervous centres: which impressions, if confined to the cord itself, excite reflex actions; whilst, if conveyed to the brain, they produce sensations. On the other hand it is equally evident, that the anterior roots are composed of *efferent* or *motor* fibres, which serve to convey to the muscles the motor impulses originating in the nervous centres; these impulses may be occasioned by the reflex action of the Spinal cord; or they may descend from the Brain, where they have been generated by an act of the will. In the accompanying Diagram, the *left* side shows the supposed composition of the *posterior* roots of the nerves; and the *right* side, that of the *anterior*.

Fig. 143.

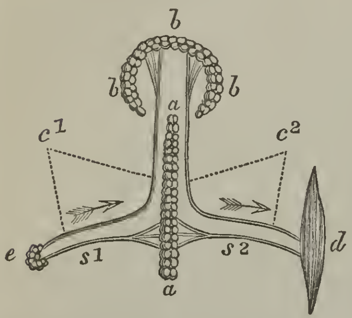


Diagram of the origins and terminations of the different groups of nervous fibres:—*a*, *a*, vesicular substance of the spinal cord; *b*, *b*, *b*, vesicular substance of the brain; *e*, vesicular substance at the commencement of afferent nerve, which consists of c^1, the cerebral division, or sensory nerve passing on to the brain, and s^1, the spinal division, or excitor nerve, which terminates in the vesicular substance of the spinal cord: on the other side we have the efferent or motor nerve proceeding to the muscle *d*, likewise consisting of two divisions,—c^2, the cerebral portion, proceeding from the brain, and conveying the influence of the will or of instinct; and s^2, the spinal division, conveying the reflex power of the spinal cord.

881. The Spinal Cord is a completely *double* tract; being composed of two distinct halves, united together on the median plane by numerous commissural fibres. This union is much closer in Man and the Mammalia than it is in the lower Vertebrata; but the division is still marked externally, by a deep fissure on the anterior surface of the cord, and by a shallower one on its posterior aspect. Its surface is traversed,

moreover, by two furrows on each side; so that each half is divided into three columns, the *anterior*, *lateral*, and *posterior*. The anterior roots of the spinal nerves join the Cord for the most part along the line of the anterior furrow; and the posterior along the line of the posterior furrow; so that the middle or lateral column lies between them, the anterior column being altogether in front of them, and the posterior column behind them. When a transverse section of the Cord is made, it is seen to contain, on each side, a crescentic patch of gray or vesicular substance; the points of each crescent are directed towards the anterior and posterior furrows of its own side respectively; whilst the convexities of the two crescents approach one another near the median plane, and are connected by a transverse tract of gray matter. The remainder of the cord is made up of white or tubular substance, the course of whose fibres is, for the most part, longitudinal.—The posterior peak of the crescentic patch of gray matter approaches very closely to the bottom of the posterior furrow; whilst the anterior peak does not come into nearly the same degree of proximity with the bottom of the anterior furrow. Hence it is considered by some, that the lateral or middle columns of the cord, being much less completely isolated from the anterior columns than they are from the posterior, should be associated with the former, under the name of *antero-lateral* columns.

882. Upon tracing the roots of the nerves into the substance of the Cord, the connection of a part of their fibres with its gray or vesicular substance is easily made evident. Of these fibres, therefore, it serves as the proper ganglionic centre. There is reason to believe, both from anatomical investigation, and from physiological phenomena, that, as in the Articulata, (§ 857,) a part of the afferent or excitor fibres, after traversing the gray substance, pass out on the *same* side as the efferent or motor; whilst another portion crosses to the *opposite* side, and forms part of *its* efferent trunks. The continuity of other fibres, however, with the longitudinal fibres that form the white strands of the Spinal Cord, has not been yet clearly demonstrated; though the analogy of the ventral cord in Articulated animals, and the physiological phenomena, which show the direct connection between the sensory surfaces and the brain on the one hand, and between the brain and the muscles on the other, would seem to indicate that such continuity must exist.—The relative proportions of the gray and white matter in the Spinal Cord differ considerably at its different parts. Thus in the cervical region, there is an enlargement corresponding with the origins of the nerves that form the brachial plexus; this enlargement is partly caused by an increase in the amount of gray matter; but the whole of the cervical portion of the cord contains a very large amount of fibrous structure also. On the other hand, there is a still greater enlargement of the cord in the lumbar region, at the part whence the nerves of the lower extremities arise; and this enlargement is caused by the great increase in the amount of the gray matter at that point; the white or fibrous portion constituting but a comparatively small part of it. Now

these anatomical facts harmonize well with the physiological views just given; for the actions of the lower extremities being much more of a simply reflex nature than those of the upper, we find the *ganglionic* portion of the spinal cord exhibiting a corresponding increase at the origins of their nerves; whilst the actions of the superior extremities being for the most part of a voluntary character, we find that the cord mainly consists, at the part with which *their* nerves are connected, of white fibrous structure, which appears to convey to those nerves the direct influence of the brain.

883. It was supposed by Sir C. Bell (who was the first to determine the relative functions of the two roots of the spinal nerves in Vertebrated animals), that the anterior columns of the Spinal cord have a function corresponding to that of the anterior roots of the spinal nerves; and the posterior columns with the posterior roots. But from the difficulty of tracing the connection between the longitudinal fibres of the cord and any portion of the roots, it is at present impossible to say how far there is any anatomical reason for the assumption of this correspondence; and it is quite certain, that the physiological facts at present known, from observation of the effects of disease or injury upon different tracts of the spinal cord, do not bear out the supposition. As to what the precise functions of the several columns are, however, it is not easy to form any other conjecture, that shall be consistent with all the phenomena at present known.

884. Of the particular Reflex actions to which the Spinal Cord (using that term in its limited sense, as excluding the Medulla Oblongata) is subservient, those most connected with the organic functions have already been noticed. They are chiefly of an *expulsive* kind; being destined to force out the contents of various cavities of the body. Thus the ordinary acts of defecation and urination, the ejaculatio seminis, and parturition, are all reflex actions, over which the will has a greater or less degree of control; being able to keep the two former ones in check, so long as the stimulus is not very violent, and being also capable of effecting them by itself; but having no control over the two latter, either by way of acceleration or prevention, when once the stimulus by which they are excited has come into full action.—The movements of the posterior extremities are among the most remarkable of those, which seem due to the action of the proper Spinal Cord. It has been already noticed, that these may be excited, even in Man, when the spinal cord has been severed in the middle without injury to its lower segment; and it is remarkable, that gentle stimuli, applied to the skin of the sole of the foot, appear the most capable of producing them. We have seen how completely, in the lower animals, the acts of progression may be sustained, by the repeated stimulus of the contact of the ground, or of fluid, without any influence from the cephalic ganglia; the power of these being limited, it would seem, to the control and direction of them. And there is strong reason to believe that, so far as the ordinary acts of locomotion are concerned, the movements of the inferior extremities in Man may be performed on the

same plan, being continued by reflex power, when once set in action by the will, whilst we are walking steadily onwards,—the mind being at the same time occupied by some train of thought which engrosses its whole attention. There are few persons to whom it has not occasionally happened that, on awaking (as it were) from their revery, they have found themselves in a place very different from that to which they had intended going; and even when the mind is sufficiently on the alert to guide, direct, and control the motions of the limbs, their separate actions appear to be performed without any direct agency of the will. It is certain that, in Birds, the movements of flight may be performed after the removal of the Cerebrum.

885. There are many irregular or abnormal reflex actions, performed through the instrumentality of the Spinal Cord, the study of which is of the highest importance to the Medical Man. It is probable that *all* Convulsive movements are produced through its agency and that of the Medulla Oblongata; for it has been found, by repeated experiments, that these movements are never produced by injuries of the Cerebral hemispheres.—Convulsive movements may be of three kinds. 1. They may be simply *reflex;* being the natural result of some extraordinary irritation. 2. They may be simply *centric;* depending upon a peculiar condition of the ganglionic centre of the Spinal Cord, which occasions muscular movements without any stimulation. 3. They may depend upon the combined action of both principles; the nervous centres being in a very irritable state, which causes very slight irritations (such as would otherwise be inoperative) to excite violent reflex or convulsive movements. This last is by far the most common cause of the convulsive actions, that occur in various diseased conditions of the system. Thus, convulsions are not unfrequent in children, during the period of teething; being produced by the irritation which results from the pressure of the tooth as it rises against the unyielding gum. In this case, the stimulus would scarcely be sufficient to produce the violent result, were it not for a peculiarly excitable state of the Spinal Cord, brought about by various causes. In like manner, when such an excitable state exists, convulsions may be occasioned by the presence of intestinal worms, of irritating substances, or even simply of undigested matters in the alimentary canal; and will cease as soon as they are cleared out—in the same manner as the convulsions of teething may often be at once checked—by the free lancing of the gums.

886. The influence of the condition of the Spinal Cord itself is peculiarly seen in the convulsive diseases termed Hydrophobia, Tetanus, Epilepsy, and Hysteria. In the first of these, not only the Spinal Cord, but the Medulla Oblongata, and the ganglia of Special Sense, are involved; their peculiar condition being the result, it would appear, of the introduction of a poison into the blood. It is most remarkable that the Brain should so completely escape its influence. When the state of intense excitability in these centres is once established, the slightest stimulus is sufficient to bring about

convulsive movements of the utmost violence. It is characteristic of this complaint, that the stimuli most effectual in exciting the movements, are those which act through the nerves of special sense; thus the *sight* or the *sound* of water will bring on the paroxysm; and any attempt to *taste* it increases the severity of the convulsions.—In Tetanus there appears to be a similarly excitable state of the Spinal Cord and Medulla Oblongata, not involving the ganglia of special sense. This may be the result of causes altogether internal, as in the idiopathic form of the disease; in which the condition exactly resembles that which may be artificially induced by the administration of Strychnine, or by its application to the cord. Or it may be first occasioned by some local irritation, as that of a lacerated wound; the irritation of the injured nerve being propagated to the nervous centres, and establishing the excitable state in them. When the complaint has once established itself, the removal of the original cause of irritation (as by the amputation of the injured limb) is seldom of any avail; since the slightest impressions upon almost any part of the body, are sufficient to excite the tetanic spasm.—In like manner, Epilepsy, which consists in convulsive actions with temporary suspension of the functions of the brain, may result from the irritation of local causes, like the convulsions of teething; and may, like them, cease when the sources of irritation are removed. But when it becomes confirmed, it seems to involve a disorder of the nervous centres, which no local treatment can influence.

887. These and other forms of Convulsive disorder, when productive of a fatal result, usually act by suspending the respiratory movements; the muscles which effect these being fixed by the spasms, so that the air cannot pass either in or out, and suffocation takes place as completely as if the entrance to the air-passages were closed. It is remarkable that every one of them may be imitated by *Hysteria;* a state of the nervous system in which there is a peculiar excitability, but in which there is no such fixed tendency to irregular action as would indicate any positive disease,—one form of convulsion often taking the place of another, at short intervals, with the most wonderful variety. It will often be found, that the convulsions may be immediately traced to some local irritation; thus they are particularly liable to occur at the catamenial periods, especially if the menstrual flux be deficient. But the liability to them, resulting from the peculiar excitability of the nervous system, can only be treated by such constitutional remedies as tend to increase its vigour and to promote its normal activity.

888. The statement that the spinal nerves arise by double roots, is not without exception as regards some, which arise from its cranial prolongation, and which are distributed to the parts of the head and neck. The *first spinal* nerve, or *sub-occipital*, (the 10th pair of Willis,) not unfrequently arises by a single set of roots, from the anterior portion of the cord; and it is then purely motor except in virtue of its inosculation with other nerves. The *Hypoglossal* (9th pair of

Willis) appears to be also a purely motor nerve; arising by one set of roots; and being distributed entirely to the *muscles* of the tongue; which organ derives its sensibility from other nerves. The *Glosso-Pharyngeal* usually arises from a single set of roots, and these correspond with the posterior roots of the spinal nerves; in some animals, however, and occasionally in man, there is a distinct anterior root, and the nerve acquires direct motor functions. It may in some respects be considered as making up, with the preceding, an ordinary spinal nerve. The *Spinal Accessory*, again, appears to be chiefly or entirely a motor nerve at its origin; and in like manner the *Pneumogastric*, or Par Vagum, seems at its roots to correspond with the posterior roots of the ordinary spinal nerves, and to execute functions analogous to theirs; but these two nerves exchange fibres, so that each acquires in part the endowments of the other. The *Facial* nerve, (or portio dura of the 7th,) which is the nerve that supplies the muscles of the head in general, arises by a single root, and is exclusively motor in its properties.—except in branches which have received sensory filaments by inosculation with other nerves. The same is the case, also, with the *Motor Nerves of the Orbit*, (the 6th, 4th and 3d, of Willis,) which arise by single roots, and which have no sensory endowments but those which they obtain by inosculation with the Fifth pair.—On the other hand, the *Fifth* pair arises by a double root; that which corresponds to the anterior or motor root to the spinal nerves is very small, however, and only enters the third division of the nerve, which supplies the muscles concerned in mastication; the other root, corresponding with the posterior roots of the spinal nerves, is of large size, and its branches are distributed to the face and head, supplying them with sensibility. Thus the *sensory* division of the fifth pair being distributed, not merely to the same parts with its motor division but also to the parts which derive their motor endowments from the Facial nerve, and from the nerves of the orbit, may be regarded as making up, together with all of them, one ordinary Spinal nerve.

4. *Functions of the Medulla Oblongata.*

889. This portion of the nervous centres, as already stated, does not differ in any essential particular from the Spinal Cord, of which it may be considered as a cranial prolongation. But the arrangement of its constituent parts is peculiar; being the medium by which the various strands of the Spinal Cord are connected with the different portions of the Encephalon: and it is also remarkable as being the ganglionic centre, concerned in the maintenance of the action of respiration, and in the ingestion of food. Four principal tracts of nervous matter may be distinguished in each of its lateral halves. These are, anteriorly, the *anterior pyramids;* next, the *olivary* bodies; next, the *restiform* bodies; and, lastly, the *posterior* pyramids. The following are the principal connections of these different strands, with

the several parts of the Encephalon above, and of the Spinal Cord below.

890. The *Anterior Pyramids*, which consist entirely of fibrous structure, may be said to connect the motor fibres of the Cerebral Hemispheres with the antero-lateral columns of the Spinal Cord. Of the fibres of which they are composed, a large part decussate; those that proceed from the right hemisphere, passing into the left side of the cord; and those from the left hemisphere into the right side of the cord,—an arrangement which fully explains the fact, that in Hemiplegia, the paralytic affection of the body is on the opposite side to that of the face, the latter corresponding with the side of the brain in which the disease may exist. A small proportion of the fibres of the anterior pyramids does not decussate; and this passes down, with fibres from the olivary columns, into the anterior columns of the cord; whilst the decussating fibres dip more deeply away from the anterior surface of the cord, and connect themselves rather with its middle columns.

891. The *Olivary* bodies are composed externally of fibrous structure; their fibres being connected above with the Cerebral Hemispheres and Corpora Quadrigemina; and below with the antero-lateral columns of the Spinal Cord. But beneath the fibrous layer we find a large mass of vesicular matter, the presence of which gives to the Medulla Oblongata its ganglionic character. This seems to be the centre of the respiratory nerves; it is continuous with the gray matter of the Spinal Cord below, and with that of certain parts of the Encephalon above; and, from its peculiar aspect, it is known as the *corpus dentatum*.

892. The *Restiform* columns are continuous above with the fibres of the hemispheres of the Cerebellum; and below they pass, without decussation, chiefly into the posterior columns of the spinal cord,—a band of *arciform* fibres, however, crossing over to the anterior columns on each side.

893. The *Posterior Pyramids* are two small strands of fibrous structure, lying between the two restiform bodies; and occupying the portion of the Medulla Oblongata on either side of the posterior median furrow. They seem to stop short at the fourth Ventricle; and it has not yet been ascertained whether they have any connection with the higher parts of the Encephalon. Below, they assist in forming the posterior columns of the Spinal Cord; and, if it be true that they have no connection with the brain, we may assign to them the function of connecting the different segments of the cord with each other.

894. The functions of the Medulla Oblongata are, therefore, of a double character;—to bring the higher parts of the Encephalon into connection with the Spinal Cord and the Nerves that issue from it;—and to serve as a centre for the reflex movements, performed through the nerves that issue from it. In both respects it corresponds precisely with any segment of the Spinal Cord itself; and there is no

reason to believe, that it possesses any other or more special endowments. The importance, however, of the reflex acts of Respiration and Deglutition, over which it presides, causes this portion of the Medulla to be the one whose integrity is most essential to the preservation of life; and therefore it *seems* to possess a character more distinctive than it really has.

895. The chief *excitor* nerve of the respiratory movements, as already stated (§§ 685–687) is the afferent portion of the Par Vagum; but the afferent portion of the Fifth pair is also a powerful excitor; and the afferent portions of all the spinal nerves, conveying impressions from the general surface of the body, are also capable of contributing to the excitement necessary for the production of the movement.—The chief *motor* nerves are the phrenic and intercostals; which, though issuing from the Cord at a considerable space lower down, probably originate in the Medulla oblongata. The motor portions of several other spinal nerves are also partly concerned; as are also the Facial nerve, the motor portion of the Par Vagum, and the Spinal Accessory. The ordinary movements of Respiration involve little action of any motor nerves but the Phrenic and Intercostal; and it is only when an excess of the stimulus (produced for example by too long a suspension of the aërating process) excites *extraordinary* movements, that the nerves last enumerated are called into action.

896. The acts of *Prehension* of food with lips, and of *Mastication*, though usually effected by voluntary power in the adult, seem to be capable of taking place as a part of the reflex operation of the Medulla Oblongata, in the Infant, as in the lower animals. This is particularly evident in the prehension of the nipple by the lips of the infant, and the act of suction which the contact of that body (or of any resembling it) seems to excite. The experiments provided for us by nature, in the production of anencephalous monstrosities, fully prove that the integrity of the nervous connection of the lips and respiratory organs with the Medulla Oblongata, is alone sufficient for the performance of this action; and experiments upon young animals, from which the brain has been removed, establish the same fact. Thus Mr. Grainger found that, upon introducing his finger, moistened with milk, or with sugar and water, between the lips of a puppy thus mutilated, the act of suction was excited; and not merely the act of suction itself, but other movements having a relation to it; for as the puppy lay on its side, sucking the finger, it pushed out its feet, in the same manner as young pigs exert theirs in compressing the sow's dugs. This action seems akin to many of those by which the lower animals take in their food; and we may thus recognize in the Medulla Oblongata a distinct centre of reflex action for the reception and deglutition of aliment, analogous to the *stomato-gastric* ganglia of Invertebrated animals.

897. In the movements of *Deglutition*, which, as formerly explained, (§ 453,) are purely reflex, the chief *excitor* is undoubtedly the affe-

rent portion of the Glosso-pharyngeal nerve. It is found that, if the trunk of this nerve, or its pharyngeal (but not its lingual) branches, be pinched, pricked, or otherwise irritated, whilst still in connection with the Medulla Oblongata, the movements concerned in the act of swallowing are excited. The same occurs if, when the trunk of the Glosso-pharyngeal has been divided, the cut extremity in connection with the Medulla Oblongata is irritated; but little or no muscular contraction is produced by irritation of the separated extremity; whence it is apparent, that the Glosso-pharyngeal has little or no direct motor power, but acts as an excitor. In this it appears to be assisted by the branches of the Fifth pair distributed upon the fauces; and probably, also, by the branches of the Superior Laryngeal distributed upon the Pharynx. The motor influence, which is generated in respondence to the stimulus thus conveyed, appears to act chiefly through the branches of the Par Vagum, which are distributed to most of the muscles concerned in swallowing; but the Facial, the Hypoglossal, the motor portion of the Fifth, and perhaps also the motor portions of some of the Cervical nerves, are also concerned in the movement, and may effect it, though with difficulty, after the pharyngeal branches of the Par Vagum have been divided.

898. In the propulsion of the food down the Œsophagus, to which the glosso-pharyngeal nerve does not extend, the muscular contraction, so far as it is of a reflex nature, (§ 455,) must depend upon the œsophageal branches of the Par Vagum alone; their afferent portion being the excitor, and their motor portion giving the requisite stimulus to the muscles. The same must be the case in regard to the muscular contractions of the cardiac and pyloric sphincters, and of the walls of the stomach, so far as regards their dependence upon the nervous system at all; but the degree of this is doubtful.

899. There are other reflex actions of the Medulla oblongata, connected with the regulation of the aperture of the Glottis; these, which are effected through the superior and inferior laryngeal branches of the Par Vagum, will be better noticed when the actions of the Larynx are under consideration.—In like manner, the reflex action concerned in the regulation of the aperture of the Pupil will be more conveniently noticed in the sketch to be presently given of the Physiology of Vision.

5. *Functions of the Sensory Ganglia.*

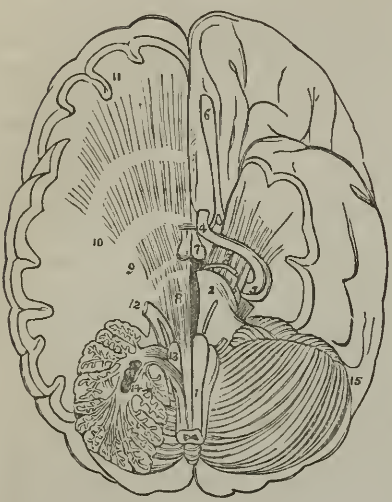
900. All the nerves of Sensation, both *general* and *special*, may be traced into a series of ganglionic masses lying at the base of the brain; which seem to constitute their own particular centres. Thus we have seen in Fishes, the Olfactive, Optic, and Auditory ganglia, marked out as such, by the termination of the nerves proceeding from the organs of smell, sight, and hearing, in these masses respectively. These ganglia bear an evident correspondence with the cephalic ganglia of the Invertebrata; which must chiefly, however, be regarded

as *optic* ganglia, since the development of the eyes far surpasses that of the other organs of special sense. On the other hand, they find their representatives in certain organs at the base of the brain, in Man and the higher Mammalia; which, though small in proportion to the whole Encephalon, are capable of being clearly marked out, as the ganglionic centres of the several nerves of sense. Thus, anteriorly, we have the *Olfactive* ganglia, in what are commonly termed the bulbous expansions of the Olfactive nerve; which, however, are real ganglia, containing gray or vesicular substance; and their separation from the general mass of the Encephalon, by the peduncles or footstalks commonly termed the trunks of the olfactory nerves, finds its analogy in many species of Fish (§ 869). The ganglionic nature of these masses is more evident in many of the lower Mammalia, in which the organ of smell is highly developed, than it is in Man, whose olfactive powers are comparatively moderate.—At some distance behind these, we have the representatives of the *Optic* Ganglia, in the *Tubercula Quadrigemina*, to which the principal part of the roots of the Optic nerve may be traced. Although these bodies are so small in Man as to be apparently insignificant, yet they are much larger, and form a more evidently important part of the Encephalon, in many of the lower Mammalia; though still presenting the same general aspect.—The *Auditory* ganglia seldom form distinct lobes or projections; but are usually lodged in the substance of the Medulla Oblongata. Their real character is most evident in certain Fishes, as the Carp; in which we find the Auditory Nerve having as distinct a ganglionic centre as the Optic. In higher animals, however, we are able to trace the Auditory nerve into a small mass of gray matter, which lies on each side of the fourth Ventricle; and although this is lodged in the midst of parts whose function is altogether different, yet there seems no reason for doubting that it has a character of its own, and that it is really the ganglion of the auditory nerve.—We are not able to fix upon any such mass of gray matter as the distinct *Gustatory* ganglion; nor is it necessary to attempt to do so; for, as we shall see hereafter, there is strong reason to regard the sense of Taste as only a refined kind of Touch.

901. At the base of the Cerebral Hemispheres, we find two ganglionic masses on either side, through which all the fibres pass that connect the Hemispheres with the Medulla Oblongata. These are the *Corpora Striata*, and *Thalami Optici*. Upon tracing forwards the tract of fibres that ascends from the anterior Pyramids, we find it passing chiefly into the Corpora Striata; whilst, if we follow the Olivary column, we shall find it to enter the Thalami. The anterior continuations of these two columns together form the *Crura Cerebri*, or peduncles of the Cerebrum; and the relative functions of the two layers of which it is composed (which may be very readily isolated) are clearly indicated, by the characters of the nerves that are respectively connected with them. Thus along the tract that passes from the anterior Pyramids to the Corpora Striata, we have none but *motor* nerves;

whilst along the tract that connects the Olivary columns with the Thalami, there are none but *sensory* nerves. The fibres of the Crura Cerebri, after entering these masses, seem to radiate towards all parts of the surface of the hemispheres, at whose base they are situated; but some of them probably find a ganglionic centre in these bodies themselves; since their substance contains a considerable amount of gray matter. It may be regarded as not improbable, then, that we may consider the Thalami as the ganglionic centres of *common* sensation; standing in the same relation to the sensory nerves, that converge from various parts of the body towards the Encephalon, as do the Optic and other ganglia to their nerves of *special* sensation. And as these last give origin (as will be presently shown) to motor fibres, so may we regard the ganglionic matter of the Corpora Striata as probably sharing in the same function; giving origin to the motor fibres, which produce the respondent consensual movements;—just as the anterior peak of gray matter in the Spinal Cord gives exit to the motor filaments, which effect the reflex movements excited through the afferent fibres that form part of the posterior roots.—It must be remembered, however, that a large proportion of the fibres, that can be traced from the Medulla Oblongata, through the Crura Cerebri, into the Thalami Optici and Corpora Striata, pass *through* these latter masses, to become continuous with the fibres radiating from them to the surface of the Cerebral hemispheres. Upon *these*, there is no reason to believe that their ganglionic matter exerts any influence.

Fig. 144.



The base of the Brain, upon which several sections have been made, showing the distribution of the diverging fibres. 1. The medulla oblongata. 2. One-half of the pons Varolii. 3. The crus cerebri crossed by the optic nerve (4), and spreading out into the hemisphere to form the corona radiata. 5. The optic nerve near its origin. 6. The olfactory nerve. 7. The corpora albicantia. On the right side a portion of the brain has been removed to show the distribution of the diverging fibres. 8. The fibres of the corpus pyramidale passing through the substance of the pons Varolii. 9. The fibres passing through the thalamus opticus. 10. The fibres passing through the corpus striatum. 11. Their distribution to the hemispheres. 12. The fifth nerve; its two roots may be traced, the one forwards to the fibres of the corpus pyramidale, the other backwards to the fasciculi teretes. 13. The fibres of the corpus pyramidale, which pass outwards with the corpus restiforme into the substance of the cerebellum; these are the arciform fibres of Solly. The fibres referred to are those below the numeral, the numeral itself rests upon the corpus olivare. 14. A section through one of the hemi spheres of the cerebellum, showing the corpus rhomboideum in the centre of its white substance; the arbor vitæ is also beautifully seen. 15. The opposite hemisphere of the cerebellum.

902. The functions of this group of ganglia may be partly inferred from the results of experiments; and these have been chiefly made

upon the Optic ganglia, or Corpora Quadrigemina. The partial loss of the ganglion on one side produces temporary blindness in the eye of the opposite side, and partial loss of muscular power on the opposite side of the body; and the removal of a larger portion, or the complete extirpation of it, occasions permanent blindness and immobility of the pupil, and temporary muscular weakness, on the opposite side. This temporary disorder of the muscular system sometimes manifests itself in a tendency to move on the axis, as if the animal were giddy; and sometimes in irregular convulsive movements.—Here, then, we have proof of the necessity of the integrity of this ganglionic centre, for the possession of the sense of vision; and we have further proof, that the ganglion is connected with the muscular apparatus, by motor nerves issuing from it. The reason why the eye of the *opposite* side is affected, is to be found in the *decussation* of the optic nerves;—a point to be immediately adverted to (§ 910). The influence of the operation on the muscles of the *opposite* side of the body, is at once understood from the fact of the decussation of the motor fibres in the anterior pyramids (§ 890).

903. Thus we see, that the Optic ganglia receive the impressions brought from the eyes by the optic nerves,—convert them, as it were into sensations,—and also transmit motor impulses to the muscular system, in respondence to those sensations. Thus they have much analogy to the cephalic ganglia of the lower animals; the greater part of whose purpose seems to be, to guide the actions of the beings to which they belong, through the sensations which they receive (§ 860). But, with a function that is probably the same, there is this important difference, as to the purpose served by these parts, in the Encephalon of Man, and of the animals that approach nearest to him in the conformation of his nervous centres. The Consensual or Instinctive movements, which make up nearly the whole of those actions in the Invertebrata that are not simply reflex, constitute a comparatively small proportion of the actions of the higher Vertebrata; *these* being guided in a much greater degree by Intelligence, which reasons upon the sensations, and devises means to gratify the desires created by them. Consequently there is reason to think, that the *direct* action of the sensory ganglia upon the muscles is comparatively seldom exercised, in the active condition of the Cerebrum. There are certain actions, however, which would seem to take place regularly through this channel. Thus the *consensual* movements of the eyes, which concur to direct their axis towards the same object, appear to depend upon the impressions made upon the retinæ; for we do not see these movements taking place with nearly the same exactness in the eyes of persons who have been born totally blind; and in those who have completely lost their sight, after having enjoyed the power of vision, we may always perceive that, although the two eyes usually move consentaneously from habit, yet that their axes are *parallel*, instead of *convergent;* so that they do not seem to look *at* any object, but *beyond* it, into vacancy.

904. The existence of a Sensation of some kind, in connection with a Muscular exertion, seems essential to the continuance of the latter. Our ordinary movements are guided by what is termed the *Muscular Sense;* that is, by a feeling of the condition of the muscle, that comes to us through its own sensory nerves. How necessary this is to the exercise of muscular power, may be best judged of from cases in which it has been lost. Thus a woman, who had suffered complete loss of sensation in one arm, but who retained its motor power, found that she could not support her infant upon it, without constantly *looking* at the child; and that, if she were to remove her eyes for a moment, the child would fall, in spite of her knowledge that her infant was resting upon her arm, and of her desire to sustain it. Here, the muscular sense being entirely deficient, the sense of vision supplied what was deficient, so long as it was exercised upon the object; but as soon as this guiding influence was withdrawn, the strongest will could not sustain the muscular contraction.—Again, in the production of vocal sounds, the nice adjustment of the muscles of the larynx, which is requisite to produce determinate tones, can only be effected in obedience to a mental conception of the tone to be uttered; and this conception cannot be formed, unless the sense of hearing has previously brought similar tones to the mind. Hence it is, that persons who are born *deaf*, are also *dumb*. They may have no malformation of the organs of speech; but they are incapable of uttering distinct vocal sounds or musical tones, because they have not the guiding conception, or recalled sensation, of the nature of these. By long training, and by efforts directed by the muscular sense of the larynx itself, some persons thus circumstanced have acquired the power of speech; but the want of sufficiently definite control over the vocal muscles, is always very evident in their use of the organ.

905. Hence, although the proper consensual actions of Man and of the higher animals are comparatively few, (the wants which these are destined to supply in the lower, being in them provided for by the exercise of intelligence,) we see that not even the proper voluntary movements can be effected, without the influence of guiding sensations, felt or conceived.—There are several actions, in regard to which it does not seem easy to say with certainty, whether they are of a simply reflex nature, or whether sensation is a necessary link in the series of changes which they involve. Such are, the act of vomiting, produced by various causes that excite nausea,—for example, by tickling the fauces with a feather; or the acts of coughing and sneezing, excited by irritation in the air-passages. In regard to these last it may be observed, that although the *ordinary* movements of Respiration are undoubtedly of a purely reflex character, yet it seems uncertain, whether those of an *extraordinary* nature can be excited by an impression that is not *felt*. The act of sneezing is usually excited by an impression upon the 5th pair; but it may result from the action of a strong light upon the eyes, and *cannot* then be excited, unless

this produces the *sensation* of dazzling.—There are numerous cases, again, in which painful sensations appear to produce or to modify movement, in a manner that is altogether involuntary. Thus in cases of excessive irritation of the retina, rendering the eye most painfully sensitive to even a feeble amount of light, the eyelids are drawn together spasmodically; and, if they be forcibly opened, the pupil is frequently rolled beneath the upper lid, much farther than it could be carried by a voluntary effort. And in pleuritis, pericarditis, and other painful affections of the parietes of the chest, we may observe the usual movements of the ribs to be very much abridged; and if the affection be confined to one side, there is a marked curtailment in *its* movements, whilst those of the other side may take place as usual,—a difference which cannot be imitated by a voluntary effort.

906. Various other facts might be adduced, to show that, in Man, certain movements are as intimately and necessarily connected with the excitement of sensations in the sensory ganglia, as others are with the production of impressions in the ganglia of reflex action. And it may be further questioned, in the absence of any precise knowledge of the subject, whether the emotions, when so strongly excited as to act involuntarily on the body, do not operate through this group of ganglia and the fibres proceeding from them. There are many analogies between the purely *emotional* actions of Man, and the *instinctive* movements of the lower animals; each following closely upon sensations, without any exercise of the reasoning faculty; and each being performed, not merely without the mandate of the will, but often in direct opposition to it. That the Emotions, when they thus affect the body, do not operate through the same set of nervous fibres as those which convey the influence of the Will, seems proved by this fact,—that cases have occurred, in which muscles have been paralyzed to the Will, whilst they remained obedient to the Emotions; and vice versâ. Thus, in one instance, the muscles of one side of the face were palsied in such a manner, that the individual could not voluntarily close his eye, nor draw his mouth towards that side; yet when any ludicrous circumstance caused him to laugh, their usual play was manifested in the expression of his countenance. And in another case, the muscles were obedient to the will; but when the individual laughed or cried under the influence of an emotion, it was only on one side of his face. To these may be added another case, in which the right arm was completely palsied, so that the individual had not the least voluntary power over it; yet it was violently agitated, whenever he met a friend whom he desired to greet.

907. These and similar cases afford sufficient proof, that the direct influence of the Emotions on the Muscular System operates through a channel distinct from that, which conveys the influence of the Will; and when we consider how closely the Emotions are connected with the sensations which excite them, and their close analogy with the instincts of the lower animals, there seems a strong presumption in favour of the idea, that the motor nerves proceeding from the sensory

ganglia constitute their peculiar instrument of operation on the body. A very characteristic example of the immediate dependence of the actions of this class upon Sensation, is afforded by the peculiar movements which are excited by the act of *tickling*. No one can question the completely *involuntary* nature of these movements; on the other hand, they are not *reflex*, for they do not take place unless the irritation is *felt*. They strictly belong, therefore, to the *consensual* group we are at present considering. Now the tickling may produce, not merely a variety of semi-convulsive movements, tending to withdraw the body from the source of irritation, but also a tendency to laughter, and an emotional state connected with it. But it would appear that the semi-convulsive movements are immediately excited, not by the emotion, but by the sensation. For there is a great variation amongst different individuals, as to the results of the irritation; the action of laughter being excited in some, without any other effect; whilst in others, spasmodic movements of the extremities take place without any tendency to laughter, indeed with a feeling of extreme distress.

908. The influence of an excited state of the emotional system of nerves, is very strongly marked in various disordered states of the system; and particularly, as already remarked, in Hydrophobia and Hysteria (§§ 886, 887). In both these diseases, violent convulsive paroxysms are brought on, by causes that produce particular sensations, or emotions consequent upon them. The tendency to *imitation* is a most powerful cause in Hysterical subjects; the mere sight of a paroxysm in one young female, being often sufficient to produce a similar attack in a whole room-full of her companions. And there are some persons who possess the power of commanding an hysterical paroxysm at will; not by voluntarily executing the convulsive actions themselves; but by "getting up" the particular emotional condition on which it depends. There can be no doubt that many of the peculiar movements exhibited by the subjects of Mesmeric phenomena, are the result of a condition of this nature. There appears to be, in such persons, an excessive activity of the consensual and emotional system; so that very slight impressions may produce very powerful effects; especially when favoured by the strong desire, on the part of the patient, to exhibit any peculiar manifestation, that is known to be expected on the part of the bystanders,—a desire which keeps the emotional system in a state of tension, and renders it peculiarly responsive to any external influence.

909. Quitting now the functions of the Sensory ganglia, we have briefly to notice certain peculiarities in the characters of the nerves which issue from them. And of these peculiarities, there is one of a very remarkable nature, which is common to the three nerves of *special* sense,—namely, the Olfactive, Optic, and Auditory;—that they are not in the least degree endowed with *common* sensibility; so that they may be cut, stretched, pinched, &c., without producing the least pain. Consequently, the ordinary sensibility of the surfaces they supply is entirely due to the branches of the Fifth pair, which are distributed

upon them; and we may have a loss of either the *general* or the *special* sensibility of any of the organs of sense, without the other being affected, save indirectly.—Again, we do not find that irritation of these nerves produces any other purely *reflex* movements, than such as are connected with the operations of the organs of sense, in which they respectively originate. Thus the Olfactory nerve cannot, by any irritation, be made to excite a reflex movement; the only reflex action that can be excited by irritating the Optic nerve, is contraction of the Pupil; and the regulation of the tension of the Membrana Tympani (if, as is probable, this is effected by the motor power of the Facial nerve, excited by impressions made upon the organ of sense,) appears to be the only reflex action to which the Auditory nerve can minister.

910. There is a further peculiarity, of a very marked kind, attending the course of the Optic nerves; this is the crossing or decussation which they undergo, more or less completely, whilst proceeding from their ganglia to the eyes. In some of the lower animals, in which the two eyes (from their lateral position) have entirely different spheres of vision, the decussation is complete; the whole of the fibres from the right optic ganglion passing into the left eye, and *vice versâ*. This is the case, for example, with most of the Osseous Fishes (as the cod, halibut, &c.); and also, in great part at least, with Birds. In the Human subject, however, and in animals which, like him, have the two eyes looking in the same direction, the decussation seems less complete; but there is a very remarkable arrangement of the fibres, which seems destined to bring the two eyes into peculiarly consentaneous action. The *posterior* border of the optic Chiasma is formed exclusively of *commissural* fibres, which pass from one *optic ganglion* to the other, without entering the real optic nerve. Again, the *anterior* border of the chiasma is composed of fibres, which seem, in like manner, to act as a commissure between the two *retinæ;* passing from one to the other, without any connection with the optic ganglia. The tract which lies between the two borders, and occupies the *middle* of the chiasma, is the true optic nerve; and in this it would appear that a portion of the fibres decussates, whilst another portion passes directly from each Optic ganglion into the corresponding eye. The fibres which proceed from the ganglia to the retinæ, and constitute the proper optic nerves, may be distinguished into an internal and an external tract. Of these, the *external*, on each side, passes directly onwards to the eye of *that* side; whilst the *internal* crosses over to the eye of the *opposite* side. The distribution of these two sets of fibres in the retina of each eye respectively, is such that, according to M. Mayo, the fibres from either optic ganglion will be distributed to *its own side* of *both* eyes;—the right optic ganglion being thus exclusively connected with the outer part of the retina of the right eye, and with the inner part of the retina of the left eye; and the left optic ganglion being, in like manner, connected exclusively with the outer side of the left retina, and with the inner side of the right. Now

as either side of the eye receives the images of objects, which are on the other side of its axis, it follows, if this account of their distribution be correct, that in Man, as in the lower animals, each ganglion receives the sensations of objects situated on the *opposite* sides of the body. The purpose of this decussation may be, to bring the visual impressions, which are so important in directing the movements of the body, into proper harmony with the motor apparatus; so that, the decussation of the motor fibres in the pyramids being accompanied by a decussation of the optic nerves, the same effect is produced as if neither decussated,—which last is the case with Invertebrated animals in general.

6. *Functions of the Cerebellum.*

911. Much discussion has taken place, of late years, respecting the uses of the Cerebellum; and many experiments have been made to determine them. That it is in some way connected with the powers of *motion*, might be inferred from its connection with the antero-lateral columns of the Spinal Cord, as well as with the posterior; and the comparative size of the organ, in different orders of Vertebrated animals, gives us some indication of what the nature of its function may be. For we find its degree of development corresponding pretty closely with the variety and energy of the muscular movements which are habitually executed by the species; the organ being the largest in those animals, which require the *combined* effort of a great variety of muscles to maintain their usual position, or to execute their ordinary movements; whilst it is the smallest in those, which require no muscular exertion for the one purpose, and little combination of different actions for the other. Thus in animals that habitually rest and move upon four legs, there is comparatively little occasion for any organ to combine and harmonize the actions of their several muscles; and in these, the Cerebellum is usually small. But among the more active predaceous Fishes (as the Shark),—Birds of the most powerful and varied flight (as the Swallow),—and such Mammals as can maintain the erect position, and can use their extremities for other purposes than support and motion,—we find the Cerebellum of much greater size, relatively to the remainder of the Encephalon. There is a marked advance in this respect, as we ascend through the series of Quadrumanous animals; from the Baboons, which usually walk on all-fours, to the semi-erect Apes, which often stand and move on their hind-legs only. The greatest development of the Cerebellum is found in Man; who surpasses all other animals in the number and variety of the combinations of muscular movement, which his ordinary actions involve, as well as of those which he is capable, by practice, of learning to execute.

912. From experiments upon all classes of Vertebrated animals, it has been found that, when the Cerebellum is removed, the power of walking, springing, flying, standing, or maintaining the equilibrium of the body, is destroyed. It does not seem that the animal has in

any degree lost the *voluntary* power over its individual muscles; but it cannot *combine* their actions for any general movements of the body. The *reflex* movements, such as those of respiration, remain unimpaired. When an animal thus mutilated, is laid on its back, it cannot recover its former posture; but it moves its limbs, or flutters its wings, and evidently is not in a state of stupor. When placed in the erect position, it staggers and falls like a drunken man,—not, however, without making efforts to maintain its balance. Phrenologists, who attribute a different function to the Cerebellum, have attempted to put aside these results, on the ground that the severity of the operation is alone sufficient to produce them; but as we shall presently see, many animals may be subjected to a much more severe operation,—the removal of the Cerebral hemispheres,—without the loss of the power of combining and harmonizing the muscular actions, provided the Cerebellum be left uninjured.—Thus, then, the idea of the functions of the Cerebellum, which we derive from Comparative Anatomy, seems fully borne out by the results of experiment; and it is also consistent with the indications, which may be drawn from the observations of Pathological phenomena. When the Cerebellum is affected with chronic disease, the motor function is seldom destroyed; but the same kind of want of combining power shows itself, as when the organ has been purposely mutilated. Some kind of lesion of the motor function is invariably to be observed; whilst the mental powers may or may not be affected,—probably according to the influence of the disease in the Cerebellum upon other parts. The same absence of any direct connection with the Psychical powers, is shown in the fact, that inflammation of the membranes covering it, if confined to the Cerebellum, does not produce delirium. Sudden effusions of blood into its substance may produce apoplexy or paralysis; but this may occur as a consequence of effusions into *any* part of the Encephalon, and does not indicate, that the Cerebellum has anything to do with the mental functions, or with the power of the Will over the muscles.

913. There is another doctrine, however, in regard to the functions of the Cerebellum, first propounded by Gall; which ought not to be altogether passed by. According to the system of Phrenologists, the Cerebellum is the organ of the sexual instinct; and its connection with the motor function is limited to the performance of the movements, to which that instinct leads. This doctrine derives no support, however, from the facts supplied by Comparative Anatomy; for there is a complete want of correspondence between the size of the Cerebellum in different animals, and the power of their sexual instinct.—Again, although pathology has been appealed to, as showing a decided connection between disease of the Cerebellum and affection of the Genital organs, (manifesting itself in priapism, turgescence of the testes, seminal emissions, &c.,) yet it appears, on a careful examination of evidence that such a sympathy is comparatively rare, not being displayed in more than one out of every seventeen cases of Cerebellic disease. And

where it is manifested, it is explicable quite readily by the known fact that this kind of excitement of the genital organs may be produced by excitement of the spinal cord and medulla oblongata.—Little or no light has been thrown on this question by experiment. It was asserted by Gall, that the Cerebellum is very small in castrated animals; but this assertion has been met by the most positive counter-statements on the part of Leuret, who has shown that the average weight of the Cerebellum (both absolutely, and in proportion to the weight of the entire encephalon), is even greater in Geldings than in Stallions or Mares.—It is asserted, however, that the results of observation in Man lead to a positive conclusion, that the size of the Cerebellum is a measure of the intensity of the sexual instinct in the individual. This assertion has been met by the counter-statement of others,—that no such relation exists. There are, of course, very great difficulties in regard to the collection of accurate information on this subject; and the question must be at present regarded as *sub judice.*

914. It may be added, that the idea of a special connection between the sexual instinct and the Cerebellum, is not inconsistent with the view of its function previously stated; and it would seem to derive some confirmation from the fact that an unusual amount of muscular exertion appears to have a peculiar tendency to depress the sexual passion even whilst it increases the general vigour of the system. If the Cerebellum be really connected with both kinds of functions, it does not seem unlikely that the excessive employment of it upon one, should diminish its energy in regard to the other. Further, it seems not improbable that the *Lobes* of the Cerebellum are the parts specially concerned in the regulation of the muscular movements; whilst the central portion (constituting the Vermiform process in Man, but forming the entire cerebellum of many of the lower Vertebrata, such as the Frog), may be the centre of the sexual sensations, and the instrument of the consensual actions to which they give rise.

7. *Functions of the Cerebrum.*

915. The view which has been taken of the Comparative structure of the Nervous system, in different animals, leads to the conclusion, that the Cerebral hemispheres are far from being the essential parts of the apparatus they were formerly imagined to be; and that they are on the contrary, superadded organs, of which we find no distinct representatives in the Invertebrata, and of which the first appearance (in the class of Fishes) exhibits them in the light of appendages, destined to perform some special function peculiar to Vertebrated animals. The results of the removal of the Cerebral Hemispheres, in animals to which the shock of the operation does not prove immediately fatal, fully confirm this view; and must appear extraordinary to those, who have been accustomed to regard these organs as the centre of all energy. Not only Reptiles, but Birds and Mammalia, if their physical

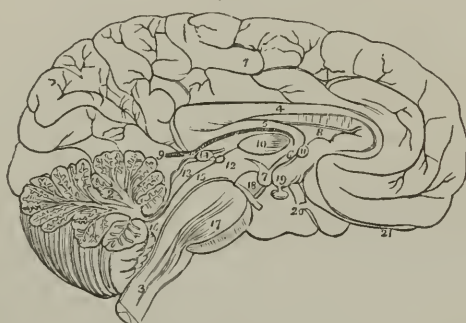
wants be supplied, may survive the removal of the whole Cerebrum for weeks, or even months. If the entire mass be taken away at once, the operation is usually fatal; but if it be removed by successive slices, the shock is less severe, and the depression it produces in the organic functions is soon recovered from. It is difficult to substantiate the existence of actual sensation, in animals thus circumstanced; but their movements appear to be of a higher kind than those resulting from mere reflex action. Thus they will eat food when it is put into their mouths; although they do not go to seek it. One of the most remarkable phenomena of such beings, is their power of maintaining their equilibrium; which could scarcely exist without consciousness. If a Rabbit, thus mutilated, be laid upon its back, it rises again; if pushed, it walks; if a Bird be thrown into the air, it flies; if a Frog be touched, it leaps. If violently aroused, the animal has all the manner of one waking from sleep; and it manifests about the same degree of consciousness as a sleeping Man, whose torpor is not too profound to prevent his suffering from an uneasy position, and who moves himself to amend it. In both cases, the movements are *consensual* only, and do not indicate any voluntary power; and we may well believe that, in the former case as in the latter, though *felt*, they are not *remembered;* an active state of the Cerebrum being essential to *memory*, though not to sensations, which simply excite certain actions.

916. As already stated, the relative amount of *Intelligence* in different animals bears so close a correspondence with the relative size and development of the Cerebral Hemispheres, that it can scarcely be questioned that these constitute the organ of the Reasoning faculties, and issue the mandates by which the Will calls the muscles into action. It must be borne in mind, however, that *size* is not by any means the only indication of their comparative development. As we advance from the lower to the higher Vertebrata, we observe a marked advance in the complexity of the structure of the Cerebrum. Its surface becomes marked by convolutions, that greatly increase the area over which blood-vessels can enter it from the surrounding membranes; and in proportion to the increase in the number and depth of these, do we find an increase in the thickness of the layer of *gray* matter, which is the source of all the powers of the organ. The arrangement of the white or fibrous tissue, which forms the interior of the mass, also increases in complexity; and as we ascend even from the lower Mammalia up to Man, we trace a marked increase in the number of the fibres, which establish communications between different parts of the organ. It is, in fact, not merely from the different parts of the gray matter, which forms the *surface* of the hemispheres, that these commissural fibres arise; but also from those isolated portions of vesicular substance, which are found in different parts of their interior; and an extremely complex system is thus formed, which is still but very imperfectly understood.

917. The two hemispheres are united on the median line by several

transverse Commissures; of which the *Corpus Callosum* is the most important. This consists of a mass of fibres very closely interlaced together; which may be traced into the substance of the hemispheres on each side, particularly at their lower part, where they are connected with the thalami optici and corpora striata. It is difficult, if not impossible, to trace its fibres any further; but there can be little doubt that they radiate, with the fibres proceeding from the bodies just named, to the different parts of the surface of the hemispheres. This commissure is altogether absent in Fish, Reptiles, and Birds; and it is partially or completely wanting in the Mammalia with least perfect brains,—as the Rodents and Marsupials.—The *anterior* commissure

Fig. 145.



The mesial surface of a longitudinal section of the brain. The incision has been carried along the middle line; between the two hemispheres of the cerebrum, and through the middle of the cerebellum and medulla oblongata. 1. The inner surface of the left hemisphere. 2. The divided surface of the cerebellum, showing the arbor vitæ. 3. The medulla oblongata. 4. The corpus callosum, curving downwards in front to terminate at the base of the brain; and rounded behind, to become continuous with 5, the fornix. 6. One of the crura of the fornix descending to 7, one of the corpora albicantia. 8. The septum lucidum. 9. The velum interpositum, communicating with the pia mater of the convolutions through the fissure of Bichât. 10. Section of the middle commissure situated in the third ventricle. 11 Section of the anterior commissure. 12. Section of the posterior commissure; the commissure is somewhat above and to the left of the numeral. The interspace between 10 and 11 is the foramen commune anterius, in which the crus of the fornix (6) is situated. The interspace between 10 and 12 is the foramen commune posterius. 13. The corpora quadrigemina, upon which is seen resting the pineal gland, 14. 15. The iter a tertio ad quartum ventriculum, or aqueduct of Sylvius. 16. The fourth ventricle. 17. The pons Varolii, through which are seen passing the diverging fibres of the corpora pyramidalia. 18. The crus cerebri of the left side, with the third nerve arising from it. 19. The tuber cinereum, from which projects the infundibulum, having the pituitary gland appended to its extremity. 20. One of the optic nerves. 21. The left olfactory nerve terminating anteriorly in a rounded bulb.

particularly unites the corpora striata of the two sides; but many of its fibres pass through those organs, and radiate towards the convolutions of the hemispheres, especially those of the middle lobe. This commissure is particularly large in those Marsupials, in which the Corpus Callosum is deficient.—The *posterior* commissure is a band of fibres which connects the optic thalami; crossing over from the posterior extremity of one to that of the other.—Besides these, there are other groups of fibres, which seem to have similar commissural functions, but which are intermingled with vesicular substance. Such are the *soft* commissure, which also extends between the thalami; the Pons Tarini, which extends between the two crura or peduncles of the cerebrum; and the Tuber cinereum, which seems to unite the

optic tracts with the thalami, the corpus callosum, the fornix, &c., and to be a common point of meeting for several distinct groups of fibres.

918. The anterior and posterior parts of the hemispheres, moreover, are connected by *longitudinal* Commissures; of which some lie above, and some below, the corpus callosum. Above the transverse fibres of the corpus callosum, there is a longitudinal tract on each side of the median line, which serves to connect the convolutions of the anterior and posterior lobes of the brain.—And above this, again, is the *superior longitudinal commissure*, which is formed by the fibrous matter of the great convolution nearest the median plane on the upper surface of the brain, and which connects the convolutions of the anterior and middle lobe with those of the posterior.—Beneath the great transverse commissure, we find the most extensive of all the longitudinal commissures, namely, the *fornix*. This is connected in front with the optic thalami, the mammillary bodies, the tuber cinereum, &c.; and behind, it spreads its fibres over the hippocampi (major and minor), which are nothing else than peculiar convolutions that project into the posterior and descending cornua of the lateral ventricles.—The fourth longitudinal commissure is the *tænia semicircularis*, which forms part of the same system of fibres with the fornix; connecting the corpus mammilare and thalamus opticus with the middle lobe of the cerebral hemisphere.—If, as Dr. Todd has remarked, we could take away the corpus callosum, the gray matter of the internal convolution, and the ventricular prominence of the optic thalami, then all these commissures fall together, and become united as one and the same series of longitudinal fibres.

919. Besides these, it is probable that the different convolutions have their own commissural fibres uniting them with each other, as well as their radiating fibres connecting them with the thalami optici and corpora striata; but these have not been certainly demonstrated. It is curious that there should be no direct communication between the Cerebral hemispheres and the Cerebellum; the only commissural band between them being the *processus a cerebello ad testes*, which passes onwards, through the tubercula quadrigemina, to the thalamus opticus on each side. This would seem to confirm the idea of the complete distinctness of their functions.

920. Very little light can be thrown by experiment upon the functions of the several parts of the Cerebral hemispheres, or of the ganglionic masses with which they are so intimately connected. In the experiments already referred to, in which the hemispheres were entirely removed, slice by slice, it was noticed that injuries of these organs neither occasion any signs of pain, nor give rise to convulsive movements. Even the thalami and corpora striata may be wounded, without the excitement of convulsions; whilst, if the incisions involve the tubercula quadrigemina, convulsions uniformly occur. It has been often observed in Man, that, when it has been necessary to separate protruded portions of the brain from the healthy part, no sensation

was produced, even though the mind was perfectly clear at the time. Hence it would appear that neither is the Cerebrum itself the centre of sensation, nor is it so connected with that centre, as to be able to convey to it sensory impressions of an *ordinary* kind. This is analogous to the condition of the nerves of *special* sense, as already remarked. That no irritation of the cerebral substance should excite convulsive movements, is a very remarkable circumstance; and it seems to indicate, that the changes which *mental* operations produce in the cerebral fibres, cannot be imitated, as changes in other motor fibres may be, by physical impressions.

921. There are various conditions, some of them natural, others morbid, in which the distinctness of the functions of the Cerebral Hemispheres is well marked. Thus in profound sleep, they seem to be entirely dormant; the Spinal system, by which the necessary *reflex* actions are carried on, being alone in a state of activity. In this condition, the Sensory ganglia also appear to be in a torpid state; but in less profound sleep, actions are often performed, which may be referred to the *consensual* group,—being such as the sensation would immediately prompt, without any reflection, and not being remembered in the waking state. Thus we turn in our beds, under the influence of an uneasy sensation; or we give some sign of recognition when our names are called. The first of these appears to be a purely consensual movement, being as *automatic* as if it were a reflex action; the other seems to have *become* as automatic, by the influence of habit, and to belong to that class, in which the mind was at first involved, but in which, after very frequent performance, the sensation suggests the action so immediately and invariably, that the action seems to take place without any concern on the part of the will. Of these *secondary automatic* actions, as they are termed, we have many examples in that condition, in which the mind, though active, is so completely absorbed by some train of thought, as to be in a state of *revery*, and to be insensible to external objects; in such a condition, the individual may continue reading aloud, playing a piece of music, or performing any other action, in which the muscular movements are immediately directed by the sensations; but he cannot carry on two distinct and independent trains of thought.

922. In the Coma of Apoplexy, Narcotic Poisoning, &c., we witness the same gradations as in ordinary sleep. When it is least profound, it seems to affect the Cerebral hemispheres alone; the Sensory Ganglia being still, in some degree, open to the reception of impressions. When complete, however, none but reflex actions can be excited; and if it advance to a fatal termination, it does so by the supervention of the same state of torpidity in the Medulla Oblongata, whereby the respiratory movements are brought to a close. These movements do not cease until the power of deglutition has been lost, and until the eye ceases to close when the edge of the lid is irritated; but when this is the case, a fatal termination may be apprehended, as

it is thus shown that the torpor is extending to the Spinal system of nerves.

923. In the condition of Dreaming, it would seem as if the Cerebrum were *partially* active; a train of thought being suggested, frequently by sensations from without; which is carried on without any controlling or directing power on the part of the Mind; and which is not corrected, or is only modified in a limited degree, by the knowledge acquired by experience. This condition is still more remarkable in Somnambulism, or (as it has been better termed) Sleep-waking; on which the dreams are not only *acted*, but may be often *acted on* with the utmost facility,—a suggestion conveyed through any of the senses excepting sight (which is usually in abeyance) being apprehended and followed up with the utmost readiness, and, in like manner, with little or no correction from experience. Between this condition, and that of ordinary dreaming, on the one hand, and that of complete insensibility on the other, there is every shade of variety; which is presented by different individuals, or by the same individuals at different times. The Cerebellum, in the Sleep-waking state, seems to be frequently in a condition of peculiar activity; remarkable power of balancing and combining the movements of the body, being often exhibited.

924. The faculty of *Memory* appears to be the exclusive attribute of the Cerebral hemispheres; no impressions made upon the Organs of Sense being ever remembered, unless they are at once registered (as it were) in this part of the nervous centres. This faculty is one of those first awakened in the opening mind of the Infant; and it is one of which we find traces in animals, that seem to be otherwise governed by pure Instinct. It obviously affords the first step towards the exercise of the reasoning powers; since no *experience* can be obtained without it; and the foundation of all intelligent adaptation of means to ends, lies in the application of the knowledge which has been acquired, and stored up in the mind. There is strong reason to believe, that no impression of this kind, once made upon the Brain, is ever entirely lost,—except through disease or accident, which will frequently destroy the memory altogether, or will annihilate the recollection of some particular class of objects or of words. All memory, however, seems to depend upon the principle of *Association;* one idea being linked with another, or with a particular sensation, in such a manner as to be called up by its recurrence; and a period of many years frequently intervening, without the combination of circumstances presenting itself, which is requisite to arouse the dormant impression of some early event. Sometimes this combination occurs in dreaming, delirium, or insanity; and ideas are recalled, of which the mind, in a state of healthy activity, has no remembrance.

925. Although there does not seem any improbability in the supposition, that different faculties of the mind should have different parts of the Cerebral hemispheres as their special instruments, yet sufficient evidence of the correctness of the (so-called) Phrenological distribution of organs, has not yet, in the Author's opinion, been adduced, to

justify its admission into an Elementary Treatise like the present; and the subject will therefore be passed by.

8. *Functions of the Sympathetic System.*

926. The Cerebro-Spinal apparatus, of which the several parts have now been described, is not the only system of ganglia and nerve-trunks, that is contained within the body of a Vertebrated animal. There is another system, having its own set of centres, and its own distribution of branches; characterized also by a peculiarity in the nature of the nervous fibres, of which its trunks are composed; and communicating at numerous points with the preceding. It will be remembered that, in front of the vertebral column, there is a series of ganglia on each side; communicating, on the one hand, with the spinal nerves, as they issue from the vertebral canal; and also connecting themselves with the two large semilunar ganglia, which lie amidst the abdominal viscera; as well as with a series of ganglia, that is found near the base of the heart. In the head, also, there are numerous scattered ganglia, which evidently belong to the same system; having numerous communications with the cephalic nerves; and being also connected with the chain of ganglia in the neck. The branches proceeding from this series of ganglia are distributed, not to the skin and muscles (like those of the cerebro-spinal system), but to the organs of digestion and secretion, to the heart and lungs, and particularly to the walls of the blood-vessels, on which they form a plexus, whose branches probably accompany their minutest ramifications. The peculiar connection of this system of nerves with the organs of vegetative life, has caused it to receive the designation of the Nervous System of Organic Life; the Cerebro-Spinal system being termed the Nervous System of Animal Life. It is also not unfrequently termed the *ganglionic* system; on account of the separation of its centres into scattered ganglia, which forms a striking contrast to the concentration that is so evident in the Cerebro-Spinal system. But this term is objectionable, as leading to a supposed analogy between this system and the general nervous system of Invertebrata, whose centres are equally scattered;—an analogy which is completely erroneous, since, as we have seen, this last is chiefly the representative of the Cerebro-Spinal system of Vertebrated animals. The term *Sympathetic* is, perhaps, the best; although it must not be supposed that the system of nerves is the instrument of by any means *all* the sympathies, which manifest themselves between different organs.

927. The Sympathetic system contains two classes of nervous fibres;—the ordinary white tubular fibres, all of which are probably derived from the Cerebro-Spinal system; and the *gray* or *gelatinous* fibres, which seem to belong exclusively to itself (§ 375). True it is, that some of these last are found in the spinal nerves; but they seem, even there, to form part of the Sympathetic system,—their centres being the ganglia on the posterior roots of the Spinal nerves,

which communicate with the true Sympathetic ganglia, and which seem to form a part of the same series. Thus we may consider each system as intermingling itself with the other;—the Cerebro-spinal system transmitting some of its fibres, both motor and sensory, into the Sympathetic;—whilst the Sympathetic is represented in the Cerebro-Spinal system, by certain fibres and collections of vesicular matter of its own. The trunks that proceed from the Semilunar ganglia, are almost entirely composed of gray or organic fibres; whence it is evident that these ganglia are to be regarded as the true centres of the Sympathetic system. On the other hand, the trunks which issue from the chain of spinal ganglia, contain a large admixture of white or tubular fibres.

928. The Sympathetic nerves possess a certain degree of power of exciting Muscular contractions, in the various parts to which they are distributed. Thus by irritating them, immediately after the death of an animal, contractions may be excited in any part of the alimentary canal, from the pharynx to the rectum, according to the trunks which are irritated,—in the heart, after its ordinary movements have ceased,—in the aorta, vena cava, and thoracic duct,—in the ductus choledochus, uterus, Fallopian tubes, vas deferens, and vesiculæ seminales. But the very same contractions may be excited, by irritating the roots of the Spinal nerves, from which the Sympathetic trunks receive their white fibres; and there is, consequently, strong reason to believe that the *motor* power of the latter is entirely dependent upon the Cerebro-spinal system. Whatever *sensory* endowments the Sympathetic trunks possess, are probably to be referred to the same connection. In the ordinary condition of the body, these are not manifested. The parts exclusively supplied by Sympathetic trunks do not appear to be in the least degree sensible; and no sign of pain is given, when the Sympathetic trunks themselves are irritated. But in certain diseased conditions of those organs, violent pains are felt in them; and these pains can only be produced, through the medium of fibres communicating with the sensorium through the spinal nerves.

929. It is difficult to speak with any precision, as to the functions of the Sympathetic system. There is much reason to believe, however, that it constitutes the channel, through which the passions and emotions of the mind affect the Organic functions; and this especially through its power of regulating the calibre of the arteries. We have examples of the influence of these states upon the Circulation, in the palpitation of the heart which is produced by an agitated state of feeling; in the Syncope, or suspension of the heart's action, which sometimes comes on from a sudden shock; in the acts of blushing and turning pale, which consist in the dilatation or contraction of the small arteries; in the sudden increase of the salivary, lachrymal, and mammary secretions, under the influence of particular states of mind, which increase is probably due to the temporary dilatation of the arteries that supply the glands, as in the act of blushing; and in many

other phenomena. It is probable that the Sympathetic system not only thus brings the Organic functions into relation with the Animal: but that it also tends to harmonize the former with each other, so as to bring the various acts of secretion, nutrition, &c., into mutual conformity. Of the distinctive function of the gray or organic fibres, we have no knowledge whatever. Possibly they may have some direct influence upon the chemical processes, which are involved in these changes, and may thus affect the *quality* of the secretions; whilst the office of the white fibres is rather to regulate the diameter of the blood-vessels supplying the glands, and thus to determine the *quantity* of their products.

CHAPTER XIII.

OF SENSATION, GENERAL AND SPECIAL.

1. *Of Sensation in general.*

930. All beings of a truly Animal Nature possess, there is good reason to believe, a *consciousness* of their own existence, first derived from a *feeling* of some of the corporeal changes taking place within themselves; and also a greater or less amount of *sensibility* to the condition of external things. This consciousness of what is taking place within and around the individual, is all derived from *impressions* made upon its afferent nervous fibres; which, being conveyed by them to the central *sensorium*, are there *felt* (§ 390). Of the mode in which the impression, hitherto a change of a physical character, is there made to act upon the *mind*, we are absolutely ignorant; we only know the fact. Although we commonly refer our various sensations to the parts at which the impressions are made,—as, for instance, when we say that we have a pain in the hand, or an ache in the leg,—we *really* use incorrect language; for though we may refer our sensations to the parts where the impression is first made on the nerves, they are really *felt* in the brain. This is evident from two facts;—first, that if the nervous communication between the part and the brain, be interrupted, no impressions, however violent, can make themselves felt; and second, that if the *trunk* of the nerve be irritated or pinched, anywhere in its course, the pain which is felt is referred, not to the point injured, but to the surface to which these nerves are distributed. Hence the well-known fact that, for some time after the amputation of a limb, the patient feels pains, which he refers to the fingers or toes that have been removed; this continues, until the irritation of the cut extremities of the nervous trunks has subsided.

931. It would seem probable that, among the lower tribes of Animals, there exists no other kind of sensibility, than that termed *general* or *common;* which exists, in a greater or less degree, in every part of the bodies of the higher. It is by this, that we feel those impressions, made upon our bodies by the objects around us, which produce the various modifications of *pain*, the sense of contact or resistance, the sense of variations of temperature, and others of a similar character. From what was formerly stated (§ 403) of the dependence of the *impressibility* of the sensory nerves, upon the activity of the circulation in the neighbourhood of their extremities, it is obvious that no parts destitute of blood-vessels can receive such impressions, or (in common language) can possess sensibility. Accordingly we find that the hair, nails, teeth, cartilages, and other parts that are altogether extra-vascular, are themselves destitute of sensibility; although certain parts connected with them, such as the bulb of the hair, or the vascular membrane lining the pulp-cavity of the tooth, may be acutely sensitive. Again, in tendons, ligaments, fibro-cartilages, bones, &c., whose substance contains very few vessels, there is but a very low amount of sensibility. On the other hand, the skin and other parts, which are peculiarly adapted to receive such impressions, are extremely vascular: and it is interesting to observe, that some of the tissues just mentioned become acutely sensible, when new vessels form in them in consequence of diseased action. It does not necessarily follow, however, that parts should be sensible in a degree proportional to the amount of blood they may contain; for this blood may be sent to them for other purposes, and they may contain but a small number of sensory nerves. Thus, it is a condition necessary to the action of Muscles, that they should be copiously supplied with blood (§ 359); but they are by no means acutely sensible; and, in like manner, Glands, which receive a large amount of blood for their peculiar purposes, are far from possessing a high degree of sensibility.

932. But besides the *general*, or *common* sensibility, which is diffused over the greater part of the body, in most animals, there are certain parts, which are endowed with the property of receiving impressions of a peculiar or special kind, such as sounds or odours, that would have no influence on the rest; and the sensations which these excite, being of a kind very different from those already mentioned, arouse ideas in our minds, which we should never have gained without them. Thus, although we can acquire a knowledge of the shape and position of objects by the touch, we could form no notion of their colour without sight, of their sounds without hearing, or of their odours without smell. The nerves which convey these *special* impressions, as already mentioned, are not able to receive those of a *common* kind; thus the eye, however well fitted for seeing, would not feel the touch of the finger, if it were not supplied by branches from the 5th pair, as well as by the Optic. Nor can the different nerves of special sensation be affected by impressions, that are adapted to ope-

rate on others; thus the ear cannot distinguish the slightest difference between a luminous and a dark object; nor could the eye distinguish a sounding body from a silent one, except when the vibrations can be *seen.* But Electricity possesses the remarkable power, when transmitted along the several nerves of special sense, of exciting the sensations peculiar to each; and thus, by proper management, this single agent may be made to produce flashes of light, distinct sounds, a phosphoric odour, a peculiar taste, and a pricking feeling, in the same individual, at one time. Each kind of sensation may also be excited, however, by *mechanical* irritation of the nerve which is subservient to it.—The feeling of *pain* may be induced by impressions made upon the nerves of special sense, as well as upon those of feeling; if these impressions be too violent or excessive. Thus the dazzling of the eye by a strong light, and still more, the action of a moderate light in an irritable state of the retina,—sudden loud sounds, or even sounds of moderate intensity but of peculiar harshness,—powerful odours, even such as are agreeable in moderation,—produce feelings of uneasiness, which may be properly called painful, even though they are different from those excited through the nerves of common sensation.

933. As a general rule, it may be stated, that the *violent* excitement of *any* sensation is disagreeable; even when the same sensation, experienced in a moderate degree, may be a source of extreme pleasure. But the question of degree is *relative*, rather than *absolute;* that is, a sensation may be felt as extremely violent by one individual; whilst another, who is more accustomed to sensations of the same kind, is not disagreeably affected by it. Thus, our sensations of heat and cold are entirely governed by the previous condition of the parts affected; as is shown by the well-known experiment, of putting one hand in hot water, the other in cold, and then transferring them both to tepid water,—which will seem cool to the one hand, and warm to the other. The same is the case in regard to light and sound, smell and taste. A person going out of a totally dark room, into one moderately bright, is for the time painfully impressed by the light, but soon becomes habituated to it; whilst another who enters it from a room brilliantly illuminated, will consider it dark and gloomy.

934. The intensity with which sensations are felt, therefore, depends upon the degree of *change* which they produce in the sensorium. The more frequent the recurrence of any particular sensation, the more does the system become adapted to it, and the less change does it produce. It is, therefore, perceived in a less and less degree, and at last it ceases to excite attention. The *stoppage* of a constantly-recurring sensation, however, will produce a change, which makes as strong an impression on the system as its first commencement; thus there are persons, who have become so habituated to the sound of a waterfall or even of a forge-hammer, that they cannot sleep anywhere but in its vicinity; and it is well known that, when a person has gone to sleep under the influence of some continuous or frequently-recurring sound (such as the voice of a reader, the dropping of water, the

tread of a sentinel, &c.), the cessation of the sound will cause his awaking.

935. The acuteness of particular sensations is influenced in a remarkable degree, by the *attention* they receive from the mind. If the mind be entirely inactive, as in profound sleep, no sensation whatever is produced by very feeble impressions; on the other hand, when the mind is from any cause strongly directed upon them, impressions very feeble in themselves produce sensations of even painful acuteness. It is in this manner, that the habit of attending to sensations of any particular class, increases their vividness; so that they are at once perceived by an individual on the watch for them, when they do not excite the observation of others. We may even, by a strong effort, direct the mind into one particular channel, so as to receive only those sensations which have reference to it, and to be unconscious *quoad* all others. Thus, the application of the mind to some particular train of thought may prevent our being conscious of anything that is going around or within us,—the conversation of friends, —the striking of the clock,—the calls of hunger, &c. This *abstraction* may be altogether voluntary; and the possession of the power of thus withdrawing the mind at will from the influence of external disturbing causes, and of fixing it upon any particular train of ideas, is an extremely valuable one. But it may also be involuntary, and may be a source of inconvenience from its tendency to recur at improper times,—producing the habitual state which is known as *absence of mind* or *revery*.

936. It is desirable that we should make a distinction, between the *sensations* themselves, and the *ideas* which are the immediate results of those sensations, when they are perceived by the mind. These ideas relate to the *cause* of the sensation, or the object by which the impression is made. Thus, the formation of the picture of an object, upon the retina, produces a certain impression upon the optic nerve; which being conveyed to the sensorium, excites a corresponding sensation, with which, in all ordinary cases, we immediately connect an idea of the nature of the object. So closely, indeed, is this idea usually related to the sensation, that we are not in the habit of making a distinction between them. Thus I may say at this moment, "I see a book on the table before me;" the fact being, that I am conscious of a certain picture, which conveys to my mind the ideas of a book and of a table, and of their relative positions; these ideas being (in Man) the result of experience and association,—in fact, originating in the immediate application of the knowledge we have previously acquired, that a certain object, whose picture we see, is a book, another object a table, and so on. We are liable to be deceived in this assumption; as when, by a clever imitation, a picture on a plane surface is made to represent an object in relief, so perfectly as at once to excite the idea of the latter,—which may not be corrected, until we have ascertained by the touch the flatness of the real object.

937. This production of ideas, by the agency of sensations, is a

process altogether mental, and dependent upon the laws of Mind. We find that some of these *perceptions* or elementary notions are *intuitive;* that is, they are prior to all experience, and are *necessarily* connected with the sensation which produces them, as reflex movements are with the impression that excites them. This seems to be the case, for example, with regard to *erect vision.* There is no reason whatever to think, that either infants or any of the lower animals see objects in an inverted position, until they have corrected their notion by the touch; for there is no reason why the inverted picture on the retina should give rise to the idea of the inversion of the object. The picture is so received by the mind, as to convey to us an idea of the position of external objects, which harmonizes with the ideas we derive through the touch; and whilst we are in such complete ignorance of the manner in which the mind becomes conscious of the sensation at all, we need not feel any difficulty about the mode in which this conformity is effected. But in Man, as already stated, the attaching definite ideas to certain groups of lines, colours, &c., with respect to the objects they represent, is a subsequent process, in which experience and memory are essentially concerned; as we see particularly well, in cases presently to be referred to, in which the sense of sight has been acquired comparatively late in life, and in which the mode of using it, and of connecting the sensations received through it with those received through the touch, has had to be learned by a long-continued training. The elementary notions thus formed,—which may, by long habit, present themselves as immediately and unquestionably, as if they were intuitive,—are termed *acquired* perceptions.

938. It is probable that, among the lower animals, the proportion of intuitive perceptions is much greater than in Man; whilst, on the other hand, his power of acquiring perceptions is much greater than theirs. So that, whilst the young of the lower animals very soon becomes possessed of all the knowledge, which is necessary for the acquirement of its food, the construction of its habitation, &c., its range is very limited, and it is incapable of attaching any ideas to a great variety of objects, of which the Human mind takes cognizance. This correspondence between the acquired perceptions of Man, and the intuitive perceptions of many of the lower animals, is strikingly evident in regard to the power of measuring distance. This is acquired very gradually by the Human infant, or by a person who has first obtained the faculty of sight later in life; but it is obviously possessed by many of the lower animals, to whose maintenance it is essential immediately upon their entrance into the world. Thus a Fly-catcher, immediately after its exit from the egg, has been known to peck at and capture an insect,—an action which requires a very exact appreciation of distance, as well as a power of precisely regulating the muscular movements in accordance with it.

2. *Of the Sense of Touch.*

939. By the sense of Touch is usually understood that modification of the common sensibility of the body of which the surface of the Skin is the especial seat, but which exists also in some of its internal reflexions. In some animals, as in Man, nearly the whole exterior of the body is endowed with it, in no inconsiderable degree; whilst in others, as the greater number of Mammalia, most Birds, Reptiles, and Fishes, and a large proportion of the Invertebrata, the greater part of the body is so covered with hairs, scales, bony or horny plates, shells of various kinds, complete horny envelops, &c., as to be nearly insensible; and the faculty is restricted to particular portions of the surface, or to organs projecting from it, which often possess a peculiarly high degree of this endowment. Even in Man, the acuteness of the sensibility of the cutaneous surface varies greatly in different parts; being greatest at the extremities of the fingers, and in the lips; and least in the skin of the trunk, arm, and thigh. Thus the two points of a pair of compasses (rendered blunt by bits of cork) can be separately distinguished by the point of the middle finger, when approximated so closely as one-third of a line; whilst they require to be opened so widely as 30 lines from each other, to be separately distinguished, when pressed upon the skin over the spine, or upon that of the middle of the arm or thigh.

940. The impressions that produce the sense of Touch are received through the sensory *papillæ*, with which the surface of the true Skin is beset,—more or less closely according to the part of it that is examined. These papillæ are minute elevations, which enclose loops of capillary vessels (Fig. 146), and branches of the sensory nerves. With regard to the precise course of the latter, there is some uncertainty; but it is probable from analogy, that the representation given of them by Gerber (Fig. 147), is in the main correct; and that each loop of the Sensory nerve is surrounded by a small quantity of vesicular matter, on some change in which the formation of the sensory impression is immediately dependent. It is peculiar to the sense of Touch, and to that of taste (which is a modification of it) that the impression must be made by the *contact* of the object itself with the sensory surface and not through any intermediate agency. The only exception to this is in regard to the sense of *Temperature*, which seems to be in many respects different from ordinary touch; here the *proximity* of the warm or cold body is sufficient,—the impressions being made after the manner of those of odours, sounds, &c. It is worth remarking, with reference to the question of the *special* nature of the

Fig. 146.

Capillary network at margin of lips.

sensory fibres, which are the channel of these impressions, that no mechanical irritation of the nerves of common sensation ever seems

Fig. 147.

Distribution of the tactile nerves at the extremity of the human thumb, as seen in a thin perpendicular section of the skin.

to excite sensations of heat or cold; these being apparently as distinct from the sense of contact, as they are from that of light or sound.

941. The only idea communicated to our minds, when this sense is exercised in its simplest form, is that of *resistance;* and we cannot acquire a notion of the size or shape of an object, or of the nature of its surface, through this sense alone, unless we *move* the object over our own sensory organ or pass the latter over the former. By the various degrees of resistance which we then encounter, we form our estimate of the hardness or softness of the body. By the impressions made upon our sensory papillæ, when they are passed over its surface, we form our idea of its smoothness or roughness. But it is through the *muscular* sense which renders us cognizant of the relative position of the fingers, the amount of movement the hand has performed in passing over the object, and of other impressions of like nature, that we acquire our notions of the size and figure of the object; and hence we perceive, that the sense of touch, without the power of giving motion to the tactile organ, would have been of comparatively little use. It is chiefly in the *variety* of movements, of which the hand of Man is capable,—thus conducive as they are, not merely to his prehensile powers, but to the exercise of his sensory endowments,—that it is superior to that of every other animal; and it cannot be doubted, that this affords us a very important means of acquiring information in regard to the external world, and especially of correcting many vague and fallacious notions, which we should derive from the sense of Sight, if used alone. On the other hand, it must be evident that our knowledge would have but a very limited range, if this sense were the only medium, through which we could acquire ideas. Of this we have the clearest evidence in the very imperfect development of the mental powers, in those unfortunate persons who have suffered under the deprivation of sight and hearing from their birth, and who have been consequently cut off from the most direct means of profiting by the knowledge possessed by their fellow-beings, through want of power to use the organs of speech. It is only where such individuals have

fallen under the care of judicious and persevering instructors, that their mental powers have been called into their due activity, or that any ideas have been awakened, beyond those immediately connected with the gratification of the animal wants, or with painful or pleasurable sensations. Thus a mind, quite capable of being aroused to activity and enjoyment, may remain in a condition nearly allied to that of idiocy, simply for want of the sensations requisite to produce ideas of a higher and more abstract character than those derived through the senses of Touch, Taste, and Smell.

942. It is not by any means certain, whether the sense of Temperature is not conveyed by a set of fibres, altogether distinct from those which minister to the proper sense of Touch or resistance. For many cases are on record, in which it has been lost, whilst the ordinary sense of touch remains; and it is sometimes preserved, when there is a complete loss of every other kind of sensibility. So again we find that the *subjective* sensations of temperature,—that is, sensations which originate from changes in the body itself, not from external impressions,—are frequently excited quite independently of the tactual sensations; a person being sensible of heat or of chilliness in some part of his body, without any real alteration of its temperature, and without any corresponding affection of the tactual sensations.—It is curious that the intensity of the sensation of temperature should depend, not merely upon the relative degree of heat to which the part is exposed (§ 933), but also upon the extent of the surface over which it is applied;—a weaker impression made on a larger surface, seeming more powerful than a stronger impression made on a small surface. Thus, if the forefinger of one hand be immersed in water at 104°, and the whole of the other hand be plunged in water at 102°, the cooler water will be thought the warmer; whence the well-known fact, that water in which a finger can be held without discomfort, will produce a scalding sensation when the entire hand is immersed in it.

3. *Of the Sense of Taste.*

943. The sense of Taste, like that of Touch, is excited by the direct contact of particular substances with certain parts of the body: but it is of a much more refined nature than touch; inasmuch as it communicates to us a knowledge of properties, which that sense would not reveal to us. All substances, however, do not make an impression on the organ of Taste. Some have a strong savour, others a slight one, and others are altogether insipid. The cause of these differences is not altogether understood; but it may be remarked that, in general, bodies which cannot be dissolved in water, alcohol, &c., and which thus cannot be presented to the gustative papillæ in a state of solution, have no taste. This sense has for its chief purpose, to direct animals in their choice of food; hence its organ is always placed at the entrance to the digestive canal. In higher animals, the tongue is the principal seat of it; but other parts of the mouth are also capable of

receiving the impression of certain savours. The mucous membrane which covers the tongue is copiously supplied with papillæ, of various forms and sizes. Those of simplest structure closely resemble the cutaneous papillæ; but there are others, which resemble clusters of such papillæ, each being composed of a fasciculus of looped capillaries (Fig. 148), and probably containing a similar fasciculus of nervous loops, lying in the midst of vesicular matter. No difference of function has yet been ascertained to exist among the several forms of lingual papillæ. When the papillæ are called into action by the contact of substances having a strong savour, they not unfrequently become very turgid, by a distension of their vessels analogous to that which occurs in *erection;* and they rise up from the surface of the mucous membrane, so as to produce a decided roughness of its surface.

Fig. 148.

Capillary network of fungiform papillæ of the tongue.

944. There has been much discrepancy of opinion as to the nerve which is specially concerned in the sense of Taste. The tongue is supplied by two sensory nerves; the lingual branch of the 5th pair; and the glosso-pharyngeal. The former chiefly supplies the upper surface of the front of the tongue, and is copiously distributed to the papillæ near the tip. The latter is mostly distributed upon the mucous surface of the fauces, and upon the back of the tongue; but it sends a branch forwards, beneath the lateral margin on each side, which supplies the edges and inferior surface of the tip of the tongue, and inosculates with the preceding. There is reason to believe, from experiment, that the gustative sensibility of the tongue is not destroyed by section of either of these nerves; though it is impaired by the total or partial loss of sensibility over certain parts of the surface. There seems good reason to conclude, that the lingual branch of the 5th pair is the nerve through which the sense of Taste, as well as that of Touch, is exercised, in the parts of the tongue to which it is specially distributed,—which are those that possess both senses in the most acute degree; and that the Glosso-pharyngeal is subservient to the same functions in the parts supplied by *it*, being probably the exclusive channel, also, through which the impressions made by disagreeable substances taken into the mouth are propagated to the Medulla Oblongata, so as to produce nausea and excite efforts to vomit. The latter nerve is also, as we have seen, the principal channel of the impressions, that give rise to the reflex act of swallowing; with which the 5th pair is concerned in a much inferior degree (§ 897).

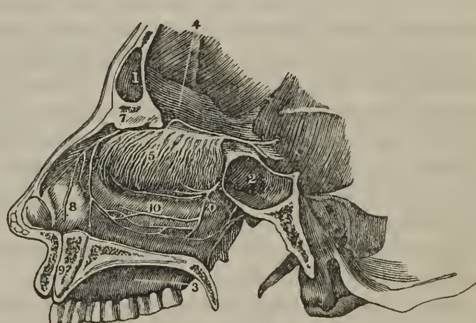
945. A considerable part of the impression produced by many substances taken into the mouth, is received through the sense of Smell, rather than through that of Taste. Of this, any one may easily satisfy himself, by closing the nostrils, and breathing through the mouth only,

whilst holding in his mouth, or even rubbing between his tongue and his palate, some aromatic substance; its taste is then scarcely recognized, although it is immediately perceived when the nasal passages are reopened, and its effluvia are drawn into them. There are many substances, however, which have no aromatic or volatile character; and whose taste, though not in the least dependent upon the action of the nose, is nevertheless of a powerful character; but these for the most part produce, by irritating the mucous membrane, a sense of *pungency*, allied to that which the same substances (acids, for instance, pepper, or mustard), will produce, when applied to the skin for a sufficient length of time, especially if the Epidermis have been removed. Such sensations, therefore, are evidently of the same *kind* with those of Touch; differing from them only in the *degree* of sensibility of the organ, through which they are received. The sense of Taste, then, in its ordinary acceptation, may be regarded as a compound of those of Smell and Touch.

4. *Of the Sense of Smell.*

946. Certain bodies possess the property of exciting sensations of a peculiar nature, which cannot be perceived by the organs of taste or touch, but which seem to depend upon the diffusion of the particles of the substance through the surrounding air, in a state of extreme minuteness. As the solubility of a substance in liquid seems a necessary condition of its exciting the sense of Taste, so does its volatility, or tendency to a vaporous state, appear requisite for its having Odorous properties. Most volatile substances are more or less odorous; whilst those which do not readily transform themselves into vapour, usually possess little or no fragrance in the liquid or solid state, but acquire strong odorous properties, as soon as they are converted into vapour,—by the aid of heat, for example. There are some solid substances, which possess very strong odorous properties, without losing weight in any appreciable degree by the diffusion of their particles through the air. This

Fig. 149.



A view of the First pair, or Olfactory Nerves, with the Nasal Branches of the Fifth pair; 1, frontal sinus; 2, sphenoidal sinus; 3, hard palate; 4, bulb of olfactory nerve; 5, branches of the olfactory nerve on the superior and middle turbinated bones; 6, spheno-palatine nerves from the second branch of the fifth pair; 7, internal nasal nerve from the first branch of the fifth; 8, branches of 7 to the Schneiderian membrane; 9, ganglion of Cloquet in the foramen incisivum; 10, anastomosis of the branches of the fifth pair on the inferior turbinated bone.

is the case, for example, with Musk; a grain of which has been kept freely exposed to the air of a room, whose door and windows were constantly open, for a period of ten years; during which time the air, thus continually changed, was completely impregnated with the odour of musk; and yet, at the end of that time, the particle was not found to have perceptibly diminished in weight. We can only attribute this result to the extreme minuteness of the division of the odorous particles of this substance. There are other odorous solids, such as Camphor, which rapidly lose weight by the loss of particles from their surface, when freely exposed to the air.

947. The conditions of the sense of Smell are very simple. The Olfactory nerve is minutely distributed over the Schneiderian membrane, which is itself highly vascular. The arrangement of the ultimate fibres of this nerve has not been ascertained. The Schneiderian membrane is kept constantly but moderately moist, by a mucous secretion from its surface; and this condition is essential to the acute perception of odours. If the mucous surface be too dry, as happens when the 5th pair is paralyzed, the sensation is blunted or even destroyed; and the same effect is produced by the presence of too copious a secretion,—as when we are suffering under an ordinary cold.—The highest part of the nasal fossæ appears to be that in which there is the most acute sensibility to odours; and hence it is that, when we *snuff* the air, so as to direct it into this portion of the cavity, we perceive delicate odours, which would otherwise have escaped us. The acuteness of the sense of Smell depends, in no small degree, upon the extent of surface exposed by the membrane lining the nasal cavity; and in this respect, Man is far surpassed by many of the lower Mammalia, especially the Ruminants, which are warned by its means of the proximity of their enemies. The habit of *attention* to sensory impressions of this class, however, very much heightens their acuteness; hence in those who suffer under blindness and deafness conjointly, it is usually the principal means by which individuals are distinguished, and the presence of strangers recognized; and there are cases, in which individuals in a state of Somnambulism have exhibited a degree of acuteness of smell, quite comparable to that which is characteristic of Deer, Antelopes, &c.

948. Besides ministering to the sense of Smell, by stimulating the secreting powers of its surface, the 5th pair has another very important function,—that of endowing the interior of the nose with *common* sensibility, and thus receiving the impression produced by acrid or pungent substances, which act upon it in the same way as they do upon the tongue. Such substances are *felt*, by the irritation they produce, rather than *smelt;* and the sensation they occasion gives rise to the consensual act of *sneezing*, by which a violent blast of air is directed through the nasal passages, in such a manner as to clear them of the irritating matter, whether solid (as snuff), fluid, or gaseous. Hence this action may be excited by the contact of an irritant with the Schneiderian membrane, after the olfactory nerve has been di-

vided, if the branches of the 5th pair be entire; whilst it does not take place when the 5th pair is paralyzed, even though the sense of smell is retained.

5. *Of the Sense of Hearing.*

949. By this sense we become acquainted with the sounds produced by bodies in a certain state of vibration; the vibrations being propagated through the surrounding medium, by the corresponding waves or undulations which they produce in it. Although air is the usual medium through which sound is propagated, yet liquids or solids may answer the same purpose. On the other hand, no sound can be propagated through a perfect vacuum.—It is a fact of much importance, in regard to the action of the Organ of Hearing, that sonorous vibrations which have been excited, and are being transmitted, in a medium of one kind, are not imparted with the same readiness to others. The following conclusions have been drawn from experimental inquiries on this subject.

I. Vibrations excited in solid bodies, may be transmitted to water without much loss of their intensity; although not with the same readiness that they would be communicated to another solid.

II. On the other hand, vibrations excited in water lose something of their intensity in being propagated to solids; but they are returned, as it were, by these solids to the liquid, so that the sound is more loudly heard in the neighbourhood of these bodies, than it would otherwise have been.

III. The sonorous vibrations are much more weakened in the transmission of solids to air; and those of air make but little impression on solids.

IV. Sonorous vibrations in water are transmitted but feebly to air; and those which are taking place in air are with difficulty communicated to water; but the communication is rendered more easy, by the intervention of a membrane extended between them.

The application of these conclusions, in the Physiology of Hearing, will be presently apparent.

950. It is on the *Auditory* nerve (commonly termed the Portio Mollis of the 7th pair), that the sonorous undulations make their impression; but we invariably find, that this impression is made through the medium of a liquid, contained in a cavity, on the walls of which the ultimate branches of this nerve are distributed. The simplest form of the organ of Hearing, such as we find in some Crustacea and certain Fishes, consists merely of a cavity excavated in the solid framework of the head; which cavity is filled with liquid, and lined by a membrane on which the auditory nerve is distributed. These animals are inhabitants of the water; and the sonorous vibrations excited in this medium, being communicated to the solid parts of the head, will be by them again transmitted to the contained fluid, without much diminution of their intensity; according to principles I. and

II.—In those Crustacea, however, which chiefly inhabit air, as well as in the greater number of the class of Fishes, we find the auditory cavity or vestibule no longer entirely closed; but having an aperture on its external side, which is covered in by a membrane. Here the vibrations of the liquid within the cavity, will be more directly excited by those of the surrounding medium; for if this be water, it will propagate its undulations into the cavity, with little interruption from the membrane stretched across its mouth; whilst, if it be air, the interposition of this very membrane will greatly assist in the transmission of the vibrations to the water of the auditory cavity, according to principle IV. In most animals, which have the organ of hearing constructed upon this simple plan, the force of the vibrations of the fluid within the cavity is increased by several minute stony concretions (termed *otolithes*), which are suspended in it. These act according to principle II. Some traces of them are found in the higher animals; in which they are for the most part superseded, however, by an apparatus better adapted to augment the intensity of the sonorous vibrations.

951. This apparatus consists, in all Vertebrated animals above the inferior Reptiles, of the tympanum or drum, with its membrane and chain of bones; together with, in the Mammalia, the external ear; which is adapted to direct itself, more or less completely, towards the point from which the sonorous vibrations proceed, and to give them a degree of preliminary concentration. The tympanic apparatus is interposed between the external ear and the membrane covering the *foramen ovale*, which is the entrance to the real auditory cavity; and its purpose is evidently to receive the sonorous vibrations from the air, and to transmit them to that membrane, in such a manner that the vibrations thus excited in the latter may be much more powerful than they would be if the air acted immediately upon it, as in the lower Vertebrata. The usual condition of the Membrana Tympani appears to be rather lax; and, when in this condition, it vibrates in accordance with grave or deep tones. By the action of the tensor tympani it may be tightened, so as to vibrate in accordance with sharper or higher tones; but it will then be less able to receive the impressions of deeper sounds. This state we may easily induce artificially, by holding the breath, and forcing air from the throat into the Eustachian tube, so as to make the membrane bulge out by pressure from within; or by exhausting the cavity by an effort at inspiration, with the mouth and nostrils closed, which will cause the membrane to be pressed inwards by the external air. In either case, the hearing is immediately found to be imperfect; but the deficiency relates only to grave sounds, acute ones being heard even more plainly than before. There is a different limit to the acuteness of the sounds, of which the ear can naturally take cognizance, in different persons. If the sound be so high in pitch, that the membrana tympani cannot vibrate in unison with it, the individual will not hear it, although it may be loud; and it has been noticed that certain individuals cannot hear the very shrill

tones produced by particular Insects, or even Birds, which are distinctly audible to others.

952. Not only do we find the tympanic apparatus superadded, in the higher forms of the organ of Hearing, but also the Semicircular Canals, and the Cochlea.—The former exist in all Vertebrata, save the lowest Fishes; and in nearly every case, they are *three* in number, and lie in three different planes. Hence it has been supposed, with some probability, that they assist in producing the idea of the *direction* of sounds. The *Cochlea* does not exist at all in Fishes; and in Reptiles its condition is quite rudimentary. In Birds, this cavity is more completely formed, though the passage is nearly straight instead of spiral; of its real character, however, there can be no doubt, from its being divided, like the Cochlea of Man, by a membranous partition, on which the ramifications of the auditory nerve are spread out. This appendage has been supposed to be the organ, that enables us to judge of the *pitch* of sounds; an idea which derives some confirmation from the correspondence between the development of the cochlea in different animals, and the variety in the pitch (or length of the scale) of the sounds, which it is important that they should hear distinctly, especially the voices of their own kind.—That the Vestibule, with the passages proceeding from it, constitutes the true organ of hearing, even in Man, is evident from the fact, that when (as not unfrequently happens) the tympanic apparatus has been entirely destroyed by disease, so as to reduce the organ to the condition of that in which no such apparatus exists, the faculty of Hearing is by no means abolished, though it is deadened.

953. The faculty of Hearing, like other senses, may be very much increased in acuteness by cultivation; but this improvement depends rather upon the habit of attention to the faintest impressions made upon the organ, than upon any change in the organ itself. This habit may be cultivated in regard to sounds of some one particular class; all others being heard as by an ordinary person. Thus, the watchful North American Indian recognizes footsteps, and can even distinguish between the tread of friends and foes; whilst his white companion, who has lived among the busy hum of cities, is unconscious of the slightest sound. Yet the latter may be a musician, capable of distinguishing the tones of all the different instruments in a large orchestra, of following any one of them through the part which it performs, and of detecting the least discord in the blended effects of the whole, —effects which would be to the unsophisticated Indian but an indistinct mass of sound. In the same manner, a person who has lived much in the country, is able to distinguish the note of every species of bird that lends its voice to the general chorus of nature; whilst the inhabitant of a town hears only a confused assemblage of shrill sounds, which may impart to him a disagreeable rather than a pleasurable sensation.

954. In all continued sounds or *tones*, there are several points to be attended to. In the first place, we take cognizance of their *pitch*;

which depends upon the *number* of vibrations in a given time,—the high notes being produced by the most rapid vibrations, and the low notes by the slowest. The ear can appreciate tones produced by 24,000 impulses per second; the pitch of which is about four octaves above the highest F of the piano-forte. On the other hand, no sequence of vibrations fewer than 7 or 8 in a second, can produce a continuous tone; because the impression left by each impulse has passed away, before the next succeeds; and there is consequently nothing more than a succession of distinct beats.—The *strength* or *loudness* of musical tones depends (other things being equal) on the force and extent of the vibrations, communicated by the sounding body to the medium which propagates them. This will diminish, however, with distance; which softens loud tones by lowering the intensity of the undulations, as a consequence of their more extensive diffusion. The cause of the differences, in the *timbre*, or quality of musical tones, —such, for instance, as those which exist between the tones of a flute, a violin, a trumpet, and a human voice, all sounding a note of the same pitch,—are unknown: but they probably depend upon differences of *form* in the undulations.—Our ideas of the *direction* and distance of sounds, are for the most part formed by habit. Of the former we probably judge in great degree, by the relative intensity of the impressions received by the two ears; though we may form some notion of it by a single ear, if the idea just stated as to the use of the semicircular canals (§ 952), be correct. Of the *distance* of the sounding body, we judge by the intensity of the sound, comparing it with that which we know the same body to produce when nearer to us. The Ear may be deceived in this respect, as well as the eye; thus the effect of a full band at a distance may be given by the subdued tones of a concealed orchestra close by us; and the Ventriloquist produces his deception, by imitating as closely as possible, not the sounds themselves, but the manner in which they would strike our ears.

6. *Of the Sense of Sight.*

955. By the faculty of Sight, we are made acquainted, in the first place, with the existence of *Light;* and by the medium of that agent, we take cognizance of the form, size, colour, position, &c., of bodies that transmit or reflect it. As to the mode in which luminous impressions are propagated through space, philosophers are at present undetermined; and the question is of no physiological importance, since all are agreed as to the *laws* which regulate their transmission. These laws, which will be found at large in any Treatise on Natural Philosophy,* may be briefly stated as follows.

I. Light travels in straight lines, so long as the medium through which it passes is of uniform density.

II. When the rays of light pass from a rarer medium into a denser

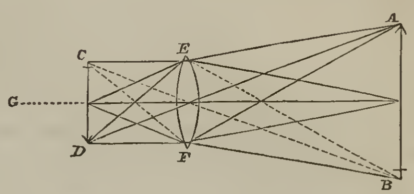
* See Dr. Golding Bird's Manual, Chap. XXII.

one, they are refracted *towards* a line drawn perpendicularly to the surface they are entering.

III. When the rays of light pass from a denser medium into a rarer one, they are refracted *from* the perpendicular.

IV. When rays proceeding from the several points of a luminous object, at a distance, fall upon a double convex lens, they are brought to a focus upon the other side of it; in such a manner that an inverted picture of the object is formed upon a screen, placed in the proper position to receive it. Thus in Fig. 150, A B is the object, and E F the lens; the rays issuing from the two extremities and the centre of the object, are brought to a corresponding focus at a less distance on the other side of it, so as to form a distinct picture; but as the rays from A are brought to a focus at D, and those from B at C, the picture will be inverted.

Fig. 150.



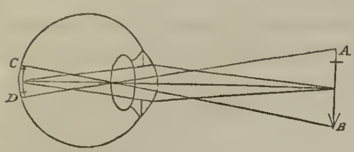
V. The further the object is removed from the lens, the nearer will the picture be brought to it, and the smaller will it be.

VI. If the screen be not held precisely in the focus of the lens, but a little nearer, or further off, the picture will be indistinct; for the rays which form it will either not have met, or they will have crossed each other.

956. The Eye, in its most perfect form—such as it possesses in Man and the higher animals,—is an optical instrument of wonderful completeness; designed to form an exact picture of surrounding objects, upon the Retina or expanded surface of the Optic nerve, by which the impression is conveyed to the brain. The rays of light, which diverge from the several points of any object, and fall upon the front of the cornea, are refracted by its convex surface, whilst passing through it into the eye, and are made to converge slightly. They are brought more closely together by the crystaline lens, which they reach after passing through the pupil; and its refracting influence, together with that produced by the vitreous humour, is such as to cause the rays, that issued from each point, to meet in a focus on the retina. In this manner, a complete inverted image is formed, as shown in Fig. 151; which represents a vertical section of the eye, and the general course of the rays in its interior. As in the preceding figure, the rays which issue from the point A are brought to a focus at D; whilst those diverging from B are made to converge upon the retina at C. The Retina, which is itself so thin as to be nearly transparent, is spread over the layer of black pigment, which lines the choroid coat. The purpose of this is evidently to *absorb* the rays of light that form the picture, immediately after they have passed through the retina; in this manner, they are prevented from being reflected

from one part of the interior of the globe to another; which would cause great confusion and indistinctness in the picture. Hence it is that, in those *albino* individuals (both of the Human race, and among the lower animals), in whose eyes this pigment is deficient, vision is extremely imperfect, except in a very feeble light; for the vascularity of the choroid and iris is such, as to give to these membranes a bright red hue, which enables them powerfully to reflect the light that reaches the interior of the eye, when they are not prevented from doing so by the interposition of the pigmentary layer.

Fig. 151.



957. The Eye is so constructed as to avoid certain errors and defects, to which all ordinary optical instruments are liable. One of these imperfections, termed *spherical aberration*, results from the fact, that the rays of light, passing through a convex lens whose curvature is circular, are *not all* brought to their proper foci; those which have passed through the exterior of the lens being made to converge sooner than those which have traversed its central portion. The result of this imperfection is, that the image is deficient in clearness, unless only the central part of the lens be employed.—The other source of imperfection is what is termed *chromatic aberration;* and it results from the unequal degree in which the differently coloured rays are refracted, so that they are brought to a focus at different points. The violet rays, being the most refrangible, are soonest brought to a focus; and the red being the least refrangible, have their focus at the greatest distance from the lens. Hence it is impossible to obtain an image by an ordinary lens, in which the colours of the object are accurately represented; for the foci of its differently coloured portions will be different; and its white rays will be decomposed, so that the outlines will be surrounded by coloured fringes.—The Optican is enabled to correct the effects of these aberrations, by combining lenses of different densities and curvatures; so arranged as to correct each others' errors, without neutralizing the refractive power. This is precisely the plan adopted in the construction of the Eye; which, when perfectly formed, and in a healthy state, forms an accurate picture of the object upon the retina, free from either spherical or chromatic aberration. This is effected by the combination of *humors* of different densities, having curvatures precisely adapted to the required purpose.

958. There are certain variations, however, in the conformation of the Eye, which diminish the perfection of its result. Thus the Cornea may be too convex, and the whole retractive power too great; so that the image of an object at a moderate distance is formed *in front* of the retina, instead of *upon* it. When this is the case, a distinct image can only be formed, by bringing the object nearer to the eye; the

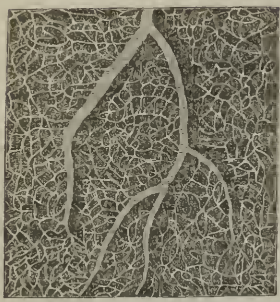
effect of which will be, to throw the picture further back. Such an eye is said to be *myopic*, or short-sighted; and its imperfection may be corrected by placing a concave lens in front of the cornea, of a curvature adapted to neutralize what is superfluous in the convexity of the latter.—On the other hand, if the cornea be too flat, and the refractive power of the humors be too low, the convergent rays proceeding from an object at a moderate distance will not meet *upon* the retina, but *behind* it (if they were allowed to pass on); consequently, the picture is indistinct; and it can only be made clear, either by withdrawing the object to a greater distance, which will bring the focus of the eye nearer to its front, or by interposing a convex lens to increase the refractive power of the eye. Such a condition is termed *presbyopic* (from its being common in aged persons), or long-sighted. It may proceed to such an extent, that not even the removal of the object to *any* distance can permit the formation of a distinct picture; so that the assistance of a convex lens must be obtained, even to see remote objects clearly; though a less degree of convexity will be required than for the clear vision of nearer objects. This state is particularly well-marked after the operation for cataract; for the removal of the crystaline lens so greatly diminishes the refractive power of the eye, as to render necessary the assistance of convex lenses of high curvature.

959. The power, by which a healthy well-formed eye can accommodate itself to the distinct vision of objects at varying distances, is a very remarkable one; and its rationale is not yet properly understood. According to the laws already stated (§ 955, V. and VI.), the picture of a near object can only be distinct when formed more remotely from the lens than the picture of a distant object. Consequently when the eye, that has been looking at a distant object, and has seen it clearly, is turned to a near object, a distant picture of the latter cannot be formed without some alteration, either in the distance between the cornea and the retina, or in the curvature of its refractive surfaces. Of the mode in which this adjustment is made, however, nothing is certainly known; the minuteness of the requisite amount of alteration being such as to prevent its precise seat from being determined.

960. The various humors and containing membranes of the Eye, thus answer the purpose of a most delicate and self-adjusting Optical instrument; the sole part, which is immediately concerned in the act of sensation, being the Retina, or net-like expansion of the Optic nerve, which lies between the black pigment and the vitreous humor. It is in this structure that the presence of *cells* at the *peripheral* as well as the *central* extremities of the afferent nerves (§ 381), may be most clearly demonstrated. They can scarcely be distinguished, in many animals, from the cells of the vesicular matter of the brain; and, like the latter, they lie in the midst of a plexus of capillary blood-vessels, which supplies the materials requisite for their growth and activity. For the maintenance of the due nutrition of this organ, it is

requisite that it should be occasionally called into use. If its functional power be destroyed, by opacity of the anterior portion of the eye, the nutrition of the retina and optic nerve suffers to such a degree that these parts cease after a time to exhibit their characteristic structure;—thus showing that the general rules already stated (Chap. VII.) in regard to the connection between the functional activity, and the due nutrition of tissues and organs, hold good with respect to the Nervous structure.—The mode in which the vesicular layer of the retina comes into relation with the network of nerve-fibres, of which it chiefly consists, has not yet been clearly ascertained.

Fig. 152.



Distribution of Capillaries in vascular layer of Retina.

961. The picture of external objects, which is formed upon the Retina, closely resembles that which we see in a Camera Obscura. It represents the outlines, colours, lights and shades, and relative positions, of the objects before us; but these do not necessarily convey to the mind the knowledge of their real forms, characters, or distances. The perception of the latter, as already remarked (§ 936), is a *mental* process; and it may be *intuitive*, or *acquired*,—the latter, it would seem, being the general condition of the function in Man, the former in the lower animals. The Infant is educating his perceptive powers, long before any indications present themselves of the exercise of higher mental faculties. By the combination, especially of the sensations of sight and touch, he is learning to judge of the surfaces of objects as they *feel*, by the *appearance* they present,—to form an idea of their *distance*, by the mode in which his eyes are directed towards them,—and to estimate their *size*, by combining the notions obtained through the picture on the retina, with those he acquires by the movement of his hands over their different parts.—A simple illustration will show how closely the ideas excited by the two sets of sensations, are blended in our minds. The idea of *smoothness* is one which has reference to the touch; and yet it constantly occurs to us, on looking at a surface which reflects light in a particular manner. On the other hand, the idea of *polish* is essentially visual, having reference to the reflection of light from the surface of the object; and yet it would occur to us from the sensation conveyed through the touch, even in the dark.

962. That this sort of combination is not intuitive in Man, but is the result of experience, is evident from the numerous observations made upon those, who had acquired the sense of Sight for the first time, after long familiarity with the characters of objects as perceived through the Touch. Thus a boy of four years old, upon whom the operation for congenital cataract had been very successfully performed,

continued to find his way about his father's house, rather by *feeling* with his hands, as he had been formerly accustomed to do, than by his newly-acquired sense of Sight; being evidently perplexed, rather than assisted, by the sensations which he derived through it. But when learning a new locality, he employed his sight, and evidently perceived the increase of facility which he derived from it. Among the many interesting particulars recorded of the youth, on whom Cheselden operated with equal success, it is mentioned that, although perfectly familiar with a *dog* and a *cat* by feeling them, and quite able to distinguish between them by his sight, he was long before he associated his *visual* with his *tactual* sensations, so as to be able to name either animal by sight alone.—The question was put by the celebrated Locke, whether a person born blind, who was able by his touch to distinguish a cube from a sphere, would, on suddenly obtaining his sight, be able to recognize each by the latter sense; the reply was given in the negative; and the experience of the cases just referred to, as well as of many others, fully justifies such an answer.

963. Still there are, even in Man, certain intuitive perceptions, which afford great assistance in the formation of ideas regarding external objects, through the visual sense. And the first of these is the power by which we recognize their erect position, notwithstanding the inversion of the image upon the retina. This is certainly not a matter of experience; nor is it capable of explanation (as some have thought) by a reference to the direction in which the rays fall upon the retina. It is the *mind* which rectifies the inversion; and, as already remarked, it is just as difficult to understand, how the inverted image on the retina should be taken cognizance of by the mind at all, as it is to comprehend how it should be thus rectified. In fact, there is no real connection whatever, between the inversion of the image upon the retina, and that wrong perception of external objects, which some have thought to be its necessary consequence. Any distortion of the picture, giving a wrong view of the *relative* positions of the objects represented, would be attended with a different result.—The same may be said of the cause of the *singleness* of the sensation perceived by the mind, although an image is formed upon the retina of *each* eye,—of those objects, at least, which lie in the field of vision that is common to both. This blending of the pictures formed upon the two retinæ into a single perception, appears to be, in part at least, the effect of habit. For when the images do not fall upon the parts of the two retinæ, which are accustomed to act together, *double vision* is the result. Thus if, when looking steadily at an object, we press one of the eyeballs sideways with the finger, we see two representations of the object; and the same thing frequently occurs as a result of an affection of the nerves or muscles of one or both eyes, (as in ordinary *strabismus* or squinting,) or from some change in the nervous centres, as in various disorders of the Encephalon, and in intoxication. If this condition should be permanent, however, we usually find that the in-

dividual becomes accustomed to the double images, or rather ceases to perceive that they *are* double; probably because the mind becomes habituated to receive the impressions from the two parts of the retina, which *now* act together. And if, after the double vision has passed away, the conformity of the two eyes be restored (as by the operation for the cure of squinting) there is double vision for some little time, although the two parts of the retina, which originally acted together, are now brought into their pristine position.

964. But the images thus combined are far from being identical; and one of the most remarkable of all our *intuitive* perceptions is that by which they are reconciled and combined, and are caused to give rise to an idea, that differs essentially from either image. No near object *can* be seen by the two eyes in the same manner; of this the reader may easily convince himself, by holding up a thin book in such a manner that its back shall be in a line with the nose, and at a moderate distance from it; and by looking at the book first with one eye, and then with the other. He will find that he gains a different view of the object with each eye, when used separately; so that if he were to represent it as he actually sees it under these circumstances he would have two perspective delineations differing from one another, because drawn from different points. But on looking at the object with the two eyes conjointly, there is no confusion between these pictures; nor does the mind dwell upon either of them singly; but the union of the two intuitively gives us the idea of a solid *projecting* body,—such an idea as we could only have otherwise acquired by the exercise of the sense of touch. That this is really the case, has been proved by experiments with a very ingenious instrument, the Stereoscope, invented by Prof. Wheatstone; which is so contrived as to bring to the two eyes, by reflection from mirrors, two different pictures, such as would be accurate representations of a solid object, as seen by the two eyes respectively. When the arrangement is such, as to bring the images of these pictures to those parts of the retinæ which would have been occupied by the images of the solid (supposing that to have been before the eyes), the mind will perceive, not one or other of the single representations of the object, nor a confused union of the two, but a body projecting in *relief*, the exact counterpart of that from which the drawings were made.—Thus the combination of the two pictures and the perception of an object different from either of them, is effected by a mental process of an instinctive kind; of the nature of which we know nothing further.

965. When two pictures, representing *dissimilar* objects, are projected upon the retinæ of the two eyes by means of the Stereoscope, the result is a curious one. The mind perceives only one of them, the other being completely excluded for a time; but it commonly happens that, after one has been seen for a short period, the other begins to attract attention and takes its place, the first entirely disappearing; so that there is no confusion or intermingling of images, except at the moment of change. The Will may determine, to a

certain extent, which object shall be seen; but not entirely; for if one picture be more illuminated than the other, it will be seen during a larger proportion of the time.—An interesting variation of this experiment may be made, without the aid of the Stereoscope, by holding a piece of blue glass before one eye, and a piece of yellow glass before the other. The result will be, not that everything will be seen of a green colour, but that the surrounding objects will be seen alternately blue and yellow;—or sometimes the field of vision will be blue, spotted with yellow; alternating with yellow spotted with blue. Thus, when we have two dissimilar objects before the eyes, our attention cannot be kept upon either, to the exclusion of the other, but is alternately and involuntarily directed, either in part or completely, to one and the other.

966. Our idea of the *distance* of near objects is evidently acquired from experience; and is suggested by the muscular sensations, which are produced by the contraction of the adductor muscles of the eyes. When we direct our eyes towards a near object, a certain degree of convergence takes place between their axes; the degree increasing as the distance between the object and the eyes diminishes; and vice versâ. We instinctively interpret the sensations thus produced, in such a manner as to be able to compare, with great accuracy, the relative distances of two objects, that are not remote from the eyes. This intuition, however, is evidently one of the *acquired* kind; as may be seen by watching the actions of an infant, or of a person who has recently become possessed of Vision. When an object is held before the eyes and an attempt is made to grasp it, the manner in which the attempt is made clearly shows, that there is no power of forming a precise idea of its situation, such as that which exists in many of the lower animals from their first entrance into the world (§ 938). The impressions made upon the eyes have to be corrected by those received through the touch, before the power of judging of distance is accomplished. How much this power depends upon the conjoint use of *both* eyes, is evident from the difficulty with which any actions, that require an exact appreciation of distance, are performed by those who have lost the sight of one eye, until they have acquired new modes of judging of it.

967. In regard to remote objects, we have not the same guide; since the convergence of the eyes, in viewing them, is so slight that the axes are virtually parallel. Our judgment of *their* distance is chiefly founded upon their apparent size, if their actual size be known to us; and also upon the extent of ground, which we see to intervene between ourselves and the object. But if we do not know their actual size, and are so situated that we cannot estimate the intervening space, we form our judgment chiefly from the greater or less distinctness of their colour and outline. Hence our idea of it will be very much affected by varying states of the atmosphere; a slight haziness increasing the apparent distance; whilst a peculiarly clear state of the air will seem to cause remote objects to approach much

more closely. This want of convergence between the axes of the two eyes, has the further effect of causing the pictures upon the two retinæ to be nearly identical; and consequently the idea of *projection* is not so strongly excited; nor are we able to distinguish with the same certainty between a well-painted picture, in which the lights and shades are preserved, and the objects themselves in relief.

968. Our notion of the *size* of an object is closely connected with that of its distance. It is founded upon the dimensions of the picture projected on the retina; and the dimensions of this picture will vary, according to the laws of optics, (§ 955,) inversely as the distance,—being, for example, twice as great when the object is viewed at the distance of one foot, as when it is carried to the distance of two feet. Where we know the relative distances of two objects, the estimation of their real comparative sizes from their *apparent* sizes, is easily effected by a simple process of mind; but this is not the case, when we only guess at their distances: and our estimate of the size of objects, even moderately remote, is as much affected by states of the atmosphere as that of their distance,—the one being, in fact, proportional to the other. Thus a slight mist, which gives the idea of increased distance, will also augment the apparent size; because, in order that an object two miles off should produce a picture upon the retina of the same extent with that made by an object one mile off, it must have double the dimensions. It is evident that our perception of the sizes of objects must be *acquired* by experience, in the same manner as that of their distance has been shown to be.

969. We have now to consider briefly some other phenomena of Vision, in which the acts of Mind, that have been just alluded to, do not participate.—The contraction of the Pupil, under the stimulus of light, seems to be affected by a sphincter muscle, which surrounds the orifice, and which is put in action by a branch of the third pair of nerves. This is an action with which the *will* has nothing to do; and it takes place entirely without our consciousness. Although it is due to the stimulus of light, yet there is reason to believe that the consciousness of the presence of light is not requisite; and that it is, therefore, a purely *reflex* action. The optic nerve seems to be the channel through which the impression is conveyed to the nervous centres; and the third pair is that through which the motor impulse is conveyed to the iris. But there is some ground for the idea, that the fifth pair may in some degree convey the requisite stimulus, when the optic nerve has been divided. How far the *dilatation* of the pupil is a muscular action, or merely one which results from the elasticity of the tissue of the iris, when the sphincter is relaxed, has not been clearly ascertained; the latter is probably the case, a permanently dilated state of the pupil being usually seen in cases where, from any cause, it is not affected by the stimulus of light. The contraction of the pupil is evidently destined to exclude from the interior of the eye, such an amount of light as would be injurious to it; whilst its dilatation in opposite circumstances admits the greatest possi-

ble number of rays. There is a contraction of the pupils, however, which takes place without any change in the amount of light. This occurs when the two eyes are made to converge strongly upon any object brought very near them; and its purpose appears to be, to prevent the rays from entering the eye at such a wide angle as would render it impossible for them to be all brought to their proper foci, and would thus produce an indistinct image.

970. In the use of the Eye, like that of the Ear, there is a tendency to blend into one continuous image a succession of luminous impressions made at short intervals; upon which fact depend a number of curious optical illusions. The length of the greatest interval that can elapse without an interruption of the presence of the image, (in other words the duration of the visual impression,) may be measured by causing a luminous object to whirl round, and by ascertaining the longest period that may be allowed for each revolution, consistently with the completeness of the circle of light thus formed. By experiments of this kind, the time has been found to vary, in different individuals, or in different states of the same individual, from about 1-4th to 1-10th of a second: that is, the impression must be repeated from four to ten times in each second, to insure the continuousness of the image.

971. The impressions of variety of *colour*, are produced by the differently coloured rays, which objects reflect or transmit to the eye. It is curious that some persons, whose sight is perfectly good for forms, distances, &c., are unable to discriminate colours. This curious affection has received the name of Daltonism, from the circumstance that the celebrated Dalton was an example of it. There are numerous modifications of it; the want of power to discriminate colour being total in some, whilst in others it extends only to certain shades of colour, or to the complementary colours.

972. When the retina has been exposed for some time to a strong impression of some particular kind, it seems less susceptible of feebler impressions of the same kind; thus if we look at any *brightly luminous* object, and then turn our eyes upon a sheet of paper, we shall perceive a *dark* spot upon it,—the portion of the retina, which had received the brighter image, not being affected by the fainter one.—Again, when the eyes have received a strong impression from a *coloured* object, the spot which is seen when the eyes are directed upon a white surface exhibits the *complementary* colour; for the retina has been so strongly affected in the part that originally received the image, by its vivid hue, that it does not perceive the fainter hue of the same kind in the object to which it is then turned, and it is impressed only by the remaining rays forming the complementary colours. This explanation applies to the phenomena of the coloured shadows which are often seen at sunset, and of those which may be seen in a room whose light enters through coloured glass or drapery. For if the prevailing light be of one colour,—orange or red for instance,—the eye will not take cognizance of that colour in the faint light of the

shadows; and will see only its complement, blue or green. If the shadow be viewed through a tube, in such a manner that the general coloured ground is excluded, it presents the ordinary tint.

CHAPTER XIV.

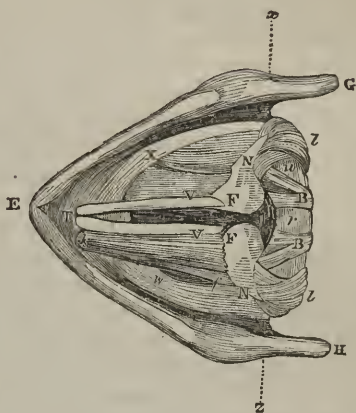
OF THE VOICE, AND SPEECH.

973. There is one particular application of Muscular power in Man, which deserves special consideration, as being that by which he effects his most complete and intimate communication with his fellows;—that, namely, by which his organ of Voice is put into action. In all air-breathing Vertebrata, the production of sound depends upon the passage of air through a certain portion of the respiratory tubes; which is so constructed as to set it in vibration, as it passes forth from the lungs.—In Reptiles, the vibrating apparatus is situated at the point, where the trachea opens into the front of the pharynx; it is of very simple construction, however, being only composed of a slit bounded by two contractile lips; and few of the animals of this class can produce any other sound than a *hiss*, which, owing to the great capacity of their lungs, is often very much prolonged.—In Birds, the situation of the vocal organ is very different. The trachea opens into the front of the pharynx, as in Reptiles, by a mere slit; the borders of which have no other movement than that of approaching one another, so as to close the aperture when necessary. This appears to be the instrument for regulating the ingress and egress of air, in conformity with the wants of the respiratory function. The *vocal* larynx of Birds is situated at the lower extremity of the trachea, just where it subdivides into the bronchial tubes; and it is of very complex construction, especially in the singing birds. In Mammalia, on the other hand, the vocal organ and the regulator of the respiration are united in the larynx, which is situated at the top of the trachea. There are few, if any, of this class, which have not some vocal sound; but the variety and expressiveness which can be given to it, differ considerably in the several orders; being by far the greatest in Man, who alone, there is reason to believe, has the power of producing articulate sounds, or proper *language*.

974. The Larynx is built up, as it were, upon the *Cricoid* cartilage (Fig. 153, x *w r u*), which surmounts the trachea, and which might be considered as its highest ring, modified in form, its depth from above downwards being much greater posteriorly than anteriorly. This is embraced, as it were, by the Thyroid cartilage (G E H); which is articulated to the sides of the Cricoid by its lower horns, round the extremities of which it may be considered to rotate, as on a pivot. In

this manner, the front of the *Thyroid* cartilage may be lifted up, or depressed, by the muscles which act upon it; whilst the position of its posterior part is but little changed. Upon the upper surface of the back of the Cricoid cartilage, are seated the two small *Arytenoid* cartilages (N F); these are so tied to the cricoid by a bundle of strong ligaments (B B), as to have a sort of rotation upon an articulating surface, which enables them to be approximated or separated from each other,—their inner edges being nearly parallel in the first case, but slanting away from each other in the second. To the summit of these cartilages are attached the *Chordæ vocales*, or vocal ligaments (T U) composed of yellow fibrous or elastic tissue. These stretch across to the front of the Thyroid cartilage; and it is upon their condition and relative situation, that the absence or the production of vocal tones, and all their modifications of pitch, depend. They are rendered tense by the depression of the front of the Thyroid cartilage, and relaxed by its elevation; by which action the *pitch* of the tones is regulated. But for the production of any vocal tones whatever, they must be brought into a nearly parallel condition, by the mutual approximation of the points of the arytenoid cartilages to which they are attached; whilst in the intervals of vocalization, these are separated, and the *rima glottidis*, or fissure between the chordæ vocales, assumes the form of a narrow V, with its point directed backwards.

Fig. 153.



Bird's-eye view of larynx from above, after Willis:—G E H, the thyroid cartilage, embracing the ring of the cricoid *r u* X *w*, and turning upon the axis *x z*, which passes through the lower horns; N F, N F, the arytenoid cartilages, connected by the arytenoideus transversus; T V, T V, the vocal ligaments; N X, the right crico-arytenoideus lateralis (the left being removed); V *k f*, the left thyro-arytenoideus (the right being removed); N *l*, N *l*, the crico-arytenoidei postici; B B, the crico-arytenoid ligaments.

975. Thus there are two sets of movements concerned in the act of vocalization:—the regulation of the relative position of the Vocal Cords, which is effected by the movements of the Arytenoid cartilages;—and the regulation of their tension, which is determined by the movements of the Thyroid cartilage. The Arytenoid cartilages are made to diverge from one another by means of the *Crico-arytenoidei postici* of the two sides, (N *l*, N *l*,) which proceed from their outer corners and turn somewhat round the edge of the Cricoid, to be attached to the lower part of its back; their action is to draw the outer corners of the Arytenoid cartilages outwards and downwards, so that the

points to which the vocal ligaments are attached are separated from one another, and the rima glottidis is thrown open. The action of these muscles is antagonized by that of the *Arytenoideus transversus*, which draws together the Arytenoid cartilages; and by that of the *Crico-arytenoidei laterales* of the two sides, (N X,) which run forwards and downwards from the outer corners of the Arytenoid cartilages, and tend by their contraction to bring together their anterior points, to which the Vocal ligaments are attached.—The depression of the front of the Thyroid cartilage, and the consequent tension of the Vocal ligaments, is occasioned by the conjoint action of the *Crico-thyroidei* of the two sides, which occasions the Thyroid and Cricoid cartilages to rotate, the one upon the other, at the articulation formed by the inferior cornua of the former; and this action will be assisted by the *Sterno-thyroidei*, which tend to depress the front of the Thyroid cartilage, by pulling from a fixed point below. On the other hand, the elevation of the front of the Thyroid cartilage, and the relaxation of the Vocal ligaments, are effected by the contraction of the *Thyro-arytenoidei* of the two sides (V *k f*), whose attachments are the same as those of the Vocal ligaments themselves; and this is aided by the *Thyro-hyoidei*, which will tend to draw up the front of the Thyroid cartilage, acting from a fixed point above.

976. The muscles which govern the aperture of the glottis,—those namely, which separate and bring together the arytenoid cartilages, and thus widen or contract the space between the posterior extremities of the vocal ligaments,—have important functions in connection with the Respiratory actions in general, and stand as guards, so to speak, at the entrance to the lungs. We can entirely close the glottis, through their means, by an effort of the Will, either during inspiration or expiration; and it is a spasmodic movement of this sort, which is concerned in the acts of Coughing and Sneezing, the purpose of which is to expel, by a sudden and powerful blast of air, any irritating substances, whether solid, liquid, or gaseous, which have found their way into the air-passages. These muscles appear to be under the sole direction of the *inferior* or *recurrent* laryngeal nerve; which seems to possess exclusively *motor* endowments. When this nerve is divided, on each side, or when the par vagum is divided above its origin, the muscles of the larynx (with the exception of the crico-thyroid) are paralyzed; and the aperture of the glottis may remain open, or may be entirely closed, according to the manner in which its lips are affected by the currents of air in egress or ingress. It is found that, under such circumstances, *tranquil* respiration may be carried on; but that any violent ingress or egress of air will tend to drive the lips of the glottis (these being in a state of complete relaxation) into apposition with each other, so as completely to close the aperture. The character of the *superior* laryngeal nerve appears to be almost exclusively *afferent;* no muscle, except the crico-thyroid, being thrown into contraction when it is irritated; whilst, on the other hand, if it be divided, neither the act of coughing, nor any

reflex respiratory movement whatever, can be excited, by irritating the lining membrane of the larynx.

977. During the ordinary acts of inspiration and expiration, the Chordæ vocales appear to be widely separated from each other, and to be in a state of the freest possible relaxation. In order to produce a vocal sound, they must be made to approach one another, and their inner faces must be brought into parallelism; both of which ends are accomplished by the rotation of the Arytenoid cartilages; whilst, at the same time, they must be put into a certain degree of tension, by the depression of the Thyroid cartilage. Both of these movements take place consentaneously, and are mutually adapted to each other; the vocal ligaments being approximated, and the rima glottidis consequently narrowed, at the same time that their tension is increased. There is a certain aperture, which is favourable to the production of each tone, although the pitch itself is governed by the tension of the Vocal Cords; and it is, perhaps, to a want of consent between the two, that the peculiarly discordant nature of some voices, which appear incapable of producing a distinct musical tone, is due.

978. It has been fully proved, by the researches of Willis, Müller, and others, that the action of the Vocal ligaments, in the production of sound, bears no resemblance to that of vibrating *strings;* and that it is not comparable to that of the mouth-piece of the flute-pipes of the Organ: but that it is, in all essential particulars, the same with that of the *reeds* of the Hautboy or Clarionet, or the *tongues* of the Accordion or Concertina. All the phenomena attending the production of Musical tones are fully explicable on this hypothesis; except the production of *falsetto* notes, which has not yet been clearly accounted for.—The power which the Will possesses, of determining, with the most perfect precision, the exact degree of tension which these ligaments shall receive, is extremely remarkable. Their average length in the Male, in the state of repose, is estimated by Müller at about 73-100ths of an inch; whilst, in the state of greatest tension, it is about 93-100ths; the whole difference, therefore, is not above 20-100ths, or one-fifth of an inch. In the female glottis, their average dimensions are about 51-100ths and 63-100ths, respectively; so that the difference is here only 12-100ths, or less than one-eighth of an inch. Now the natural compass of the voice, in most persons who have cultivated the vocal organ, may be stated at about two octaves, or 24 semitones. Within each semitone, a singer of ordinary capability could produce at least ten distinct intervals; so that for the total number of intervals, 240 is a very moderate estimate. There must, therefore, be at least 240 different states of tension of the vocal cords, every one of which can be at once determined by the will, when a distinct conception exists of the tone to be produced (§ 904); and, as the whole variation in their length is not more than one-fifth of an inch, even in Man, the variation required, to pass from one interval to another, will not be more than 1-1200th of an inch.—And yet this estimate is much below that, which might be truly made from the per-

formance of a practiced vocalist. The celebrated Madame Mara is said to have been able to sound 50 different intervals between each semitone; the compass of her voice was at least 40 semitones, so that the total number of intervals was 2000. The extreme variation in the length of the vocal cords, even taking the larger scale of the Male larynx, not being more than the fifth of an inch, it may be said that she was able to determine the contractions of her vocal muscles to the *ten-thousandth* of an inch.

979. It is on account of the greater length of the Vocal cords, that the *pitch* of the voice is much lower in Man than in Woman: but this difference does not arise until the end of the period of childhood,—the size of the larynx being about the same in the Boy and Girl, up to the age of 14 or 15 years, but then undergoing a rapid increase in the former, whilst it remains nearly stationary in the latter. Hence it is that Boys, as well as Girls and Women, sing *treble;* whilst Men sing *tenor*, which is about an octave lower than the treble; or *bass*, which is several notes lower still.—The cause of the variations in the *timbre* or *quality* in different voices, is not certainly known; but it appears to be due, in part, to differences in the degree of flexibility and smoothness in the cartilages of the larynx. In women and children, these cartilages are usually soft and flexible, and the voice is clear and smooth; whilst in men, and in women whose voices have a masculine roughness, the cartilages are harder, and are sometimes almost completely ossified. The *loudness* of the voice depends in part upon the force with which the air is expelled from the lungs; but the variations in this respect, which exist among different individuals, seem partly due to the degree in which its resonance is increased by the vibration of the other parts of the larynx, and of the neighbouring cavities. In the Howling Monkeys of America, there are several pouches opening from the larynx, which seem destined to increase the volume of tone that issues from it; one of these is excavated in the substance of the hyoid bone itself. Although these Monkeys are of inconsiderable size, yet their voices are louder than the roaring of lions, and are distinctly audible at the distance of two miles; and when a number of them are congregated together, the effect is terrific.

980. The vocal sounds produced by the action of the larynx are of very different characters; and may be distinguished into the *cry*, the *song*, and the ordinary or acquired *voice*. The cry is generally a sharp sound, having little modulation or accuracy of pitch, and being usually disagreeable in its timbre or quality. It is that by which animals express their unpleasing emotions, especially pain or terror; and the Human infant, like many of the lower animals, can utter no other sound.—In *song*, by the regulation of the vocal cords, definite and sustained musical tones are produced, which can be changed or modulated at the will of the individual. Different species of Birds have their respective songs; which are partly instinctive, and partly acquired by education. In Man, the power of song is entirely acquired;

but some individuals possess a much greater facility in acquiring it than others,—this superiority appearing to depend upon their more precise conception of the tones to be sounded, as well as their more ready imitation,—besides differences in the construction of the larynx itself. The larynx of an accomplished vocalist, obedient to the expression of the emotions, as well as to the dictates of the will, may be said to be the most perfect musical instrument ever constructed.—The *voice* is a sound more resembling the cry, in regard to the absence of any sustained musical tone; but it differs from the cry, both in the quality of its tone, and in the modulation of which it is capable by the will. In ordinary conversation, the voice passes through a great variety of musical tones, in the course of a single sentence, or even a single word,—sliding imperceptibly from one to another; and it is when we attempt to fix it definitely to a certain pitch, that we change it from the *speaking* to the *singing* tone.

981. The power of producing *articulate* sounds, from the combination of which *Speech* results, is altogether independent of the Larynx; being due to the action of the muscles of the mouth, tongue, and palate. Distinctly articulate sounds may be produced without any vocal or laryngeal tone, as when we *whisper;* and it has been experimentally shown, that the only condition necessary for this mode of speech, is the propulsion of a current of air through the mouth, from back to front. On the other hand, we may have the most perfect laryngeal tone without any articulation; as in the production of musical sounds, not connected with words. But in ordinary speech, the laryngeal tone is modified by the various organs, which intervene between the larynx and the os externum. The simplest of these modifications is that by which the *Vowel* sounds are produced: these sounds being continuous tones modified by the form of the aperture through which they pass out. Thus, let the reader open his mouth to the widest dimensions, depress the tongue, and raise the velum palati, so as to make the exit of air as free as possible; on then making a vocal sound, he will find that this has the character of the vowel *a* in *ah*. On the other hand, if he draw together the lips, still keeping the tongue depressed, he will pass to the sound represented in the English language by *oo*, in the Continental languages by *u*. By attention to the production of other vowel sounds, it will be found that they are capable of being formed by similar modifications in the form of the buccal cavity and the size of the buccal orifice; and that they are capable of being sustained for any length of time. There is an exception, however, in regard to the sound of the English *i*, as in *fine;* which is, in reality, a diphthongal sound, produced in the act of transition from a peculiar indefinite murmur to the sound of the long *e*, which takes its place when we attempt to continue it. The short vowel sounds, moreover,—such as *a* in *fat*, *e* in *met*, *o* in *pot*, &c., are not capable of being perfectly prolonged; as they require, for their true enunciation, to be immediately followed by a consonant. —A tolerably good artificial imitation of Vowel sounds has been

effected, by means of a reed-pipe representing the larynx, surmounted by an India-rubber ball, with an orifice, representing the cavity and orifice of the mouth. By modifying the form of the ball, the different vowels could be sounded during the action of the reed.

982. In the production of the sounds termed *Consonants*, the breath suffers a more or less complete interruption, in its passage through the parts anterior to the larynx. The most natural primary division of these sounds is into those which require a total stoppage of the breath at the moment previous to their being pronounced, and which, therefore, cannot be prolonged; and those in pronouncing which the interruption is partial, and which can, like the vowel sounds, be prolonged ad libitum. The former have received the designation of *explosive* consonants; the latter are termed *continuous*.—In pronouncing any consonants of the *explosive* class, the posterior nares are completely closed; and the whole current of air is directed through the mouth. This may be checked by the approximation of the lips, as in pronouncing *b* and *p;* by the approximation of the point of the tongue to the front of the palate, as in pronouncing *d* and *t;* or by the approximation of the middle of the tongue to the arch of the palate, as in pronouncing the hard *g* or *k*. The difference between *b*, *d*, and *g*, on the one hand, and *p*, *t*, and *k*, on the other, depends simply upon the greater extent of the meeting surfaces in the former case than in the latter.—In sounding some of the *continuous* consonants, the air is not allowed to pass through the nose; but the interruption in the mouth is incomplete; this is the case with *v* and *f*, *s* and *z*. In others, the posterior nares are not closed, and the air has a nearly free passage, either through the nose alone, as in *m* and *n*, or through the nose and mouth conjointly as in *l* and *r*. The sound of *h* is a mere aspiration, caused by an increased force of breath; and that of the guttural *ch*, as it exists in Welsh, Gaelic, and most Continental languages, is an aspiration modified by the elevation of the tongue, which causes a slight obstruction to the air, and an increased resonance in the back of the mouth.

983. The study of the mode in which the different Consonants are produced, is of particular importance to those who labour under defective speech, especially that difficulty which is known as *Stammering*. This very annoying impediment is occasioned by a want of proper control over the muscles concerned in Articulation; which, instead of obeying the Will, are sometimes affected with an involuntary or spasmodic action, that interrupts the pronunciation of particular words,—just as, in Chorea, the muscles of the limbs are interrupted by spasmodic twitchings, in the performance of any voluntary movement. In fact, persons affected with general Chorea, frequently stammer; showing that ordinary Stammering may be considered as a kind of local Chorea. The analogy between the two states is further indicated by the corresponding influence of excited Emotions in aggravating both.—It is in the pronunciation of the consonants of the *explosive* class, that the stammerer usually experiences the greatest

difficulty; for the total interruption to the breath, which they occasion, is frequently continued involuntarily;* so that either the expiration is entirely checked, the whole frame being frequently thrown into the most distressing semi-convulsive movements, or the sound comes out in jerks. Sometimes, however, the spasmodic action occurs in the pronunciation of *vowels* and *continuous* consonants; the stammerer prolonging his expiration, without being able to check it.

984. The best method of curing this defect (where there is no malformation of the organs of speech, but merely a want of power to use them aright), is to study the particular difficulty under which the individual labours; and then to cause him to practise systematically the various movements concerned in the production of the sounds in question, at first separately, and afterwards in combination,—until he feels that his voluntary control over the muscles is complete. The patient would at first do well to practise sentences, from which the explosive consonants are omitted; his chief difficulty, arising from the spasmodic suspension of the expiratory movement, being thus avoided. Having mastered these, he may pass on to others, in which the difficult letters are sparingly introduced; and may finally accustom himself to the use of ordinary language. One of the chief points to be aimed at, is to make the patient feel that he *has* command over his muscles of articulation; and this is best done, by *gradually* leading him from that which he *can* do, to that which he fears to attempt.

* The interruption of the expiratory movement in Stammering, is usually stated to take place in the *glottis;* but the Author is satisfied that, in all ordinary cases at least, it is in that condition of the *mouth* which is preparatory to the pronunciation of one of the explosive consonants.

INDEX.

N. B. The Numbers refer to the Paragraphs.

D

E

THE END.

CATALOGUE

OF

MEDICAL AND SURGICAL WORKS,

PUBLISHED BY

LEA & BLANCHARD,

PHILADELPHIA.

July, 1850.

TO THE MEDICAL PROFESSION.

Lea & Blanchard subjoin a list of their publications in medical and other sciences, to which they would invite the attention of the Profession, with the full confidence that they will be found to correspond in every respect with the description. They are to be had of all the principal booksellers throughout the Union, from whom, or from the publishers particulars respecting price, &c., may be had on application.

Philadelphia, May, 1850.

DICTIONARIES AND JOURNALS.

American Journal of the Medical Sciences, quarterly, at $5 a year.
Cyclopædia of Practical Medicine, by Forbes, Tweedie, &c., edited by Dunglison, in 4 super royal volumes, 3154 double columned pages.
Dunglison's Medical Dictionary, 7th ed., 1 vol. imp. 8vo., 912 large pages, double columns.
Hoblyn's Dictionary of Medical Terms, by Hays, 1 vol. large 12mo., 402 pages, double columns.
Medical News and Library, monthly, at $1 a year.

ANATOMY.

Anatomical Atlas, by Smith and Horner, large imp. 8vo., 650 figures. New and cheaper ed.
Horner's Special Anatomy and Histology, 7th edition, 2 vols. 8vo., many cuts, 1130 pages.
Horner's United States Dissector, 1 vol. large royal 12mo., many cuts, 444 pages.
Maclise's Surgical Anatomy, Parts I. and II., 29 colored plates, imp. 4to. Price $2 00 each. (To be complete in 4 parts.)
Sharpey and Quain's Anatomy, by Leidy, 2 vols. 8vo., 1300 pages, 511 wood-cuts. Now ready.
Wilson's Human Anatomy, by Goddard, 4th edition, 1 vol. 8vo., 252 wood-cuts, 580 pp.
Wilson's Dissector, or Practical and Surgical Anatomy, with cuts, 1 vol. 12mo., 444 pages.

PHYSIOLOGY.

Carpenter's Principles of Human Physiology, 1 vol. 8vo., 752 pp., 300 cuts and 2 plates, 4th edition, much improved and enlarged. 1850.
Carpenter's Elements, or Manual of Physiology, 1 vol. 8vo., 566 pages, many cuts.
Dunglison's Human Physiology, 6th edition, 2 vols. 8vo., 1350 pages, and 370 wood-cuts.
Harrison on the Nerves, 1 vol. 8vo., 292 pages.
Kirkes and Paget's Physiology, 1 vol. 12mo., many cuts, 550 pages.
Matteucci on the Physical Phenomena of Living Beings, 1 vol. 12mo., 388 pp., cuts.
Roget's Outlines of Physiology, 8vo., 516 pages.
Solly on the Brain, 1 vol. 8vo., 496 pp., 118 cuts.
Todd and Bowman's Physiological Anatomy and Physiology of Man, with numerous wood-cuts. (Part published in the Medical News.)

PATHOLOGY.

Abercrombie on the Stomach, 1 vol. 8vo., 320 pp.
Abercrombie on the Brain, 1 vol. 8vo., 324 pp.
Alison's Outlines of Pathology, &c., 8vo., 420 pp.
Blakiston on Diseases of the Chest, 1 vol., 384 pp.
Blood and Urine Manuals, by Reese, Griffith, and Markwick, 1 vol. 12mo., 462 pages, 6 plates.
Budd on the Liver, 1 vol. 8vo., 392 pages, plates and wood-cuts.
Burrows on Cerebral Circulation, 1 vol. 8vo., 216 pages, with 6 colored plates.
Billing's Principles, 1 vol. 8vo., 304 pages.
Bird on Urinary Deposits, 8vo., 228 pages, cuts.
Copland on Palsy and Apoplexy, 1 vol., just ready.
Hasse's Pathological Anatomy, 8vo., 379 pages.
Hope on the Heart, new ed., pl's, 1 vol. 8vo., 572 p.
Hughes on the Lungs, &c., 1 vol. 12mo., 270 pp.
Lallemand on Spermatorrhœa; 1 vol. 8vo., 320 pp.
Mitchell on Fevers, 1 vol. 12mo., 138 pages.
Philip on Protracted Indigestion, 8vo., 240 pp.
Philips on Scrofula, 1 vol. 8vo., 350 pages.
Prout on the Stomach, &c., 1 vol. 8vo., 466 pp., colored plates.
Ricord on Venereal, new ed., 1 vol. 8vo., 340 pp.
Stanley on Diseases of the Bones, 1 vol. 8vo. 286 pages. (A new work.)
Vögel's Pathological Anatomy of the Human Body, 1 vol. 8vo., 536 pages, col. plates.
Walshe on the Lungs, 1 vol. 12mo., 310 pages.
Wilson on the Skin, 1 vol. 8vo., new ed., 440 pp. Same work, with colored plates.
Whitehead on Sterility and Abortion, 1 vol. 8vo., 368 pages.
Williams' Principles of Medicine, by Clymer, 2d edition, 440 pages, 1 vol. 8vo.
Williams on the Respiratory Organs, by Clymer, 1 vol. 8vo., 500 pages.

PRACTICE OF MEDICINE.

Ashwell on Females, 2d ed., 1 vol. 8vo., 520 pp.
Bennet on the Uterus, 2d and enlarged edition, 1 vol. 8vo., 356 pages. (Now ready.)
Bartlett on Fevers, 2d edition, 550 pages.
Benedict's Compendium of Chapman's Lectures, 1 vol. 8vo., 258 pages.
Chapman on Fevers, Gout, Dropsy, &c. &c., 1 vol. 8vo., 450 pages.
Colombat de L'Isère on Females, by Meigs, 1 vol. 8vo., 720 pages, cuts. New edition. 1850.
Condie on the Diseases of Children, 3d edition, 1 vol. 8vo., just issued, 1850.
Churchill on the Diseases of Infancy and Childhood, 1 vol. 8vo., now ready, 1850.
Churchill on the Diseases of Females, by Huston, 5th edition, revised by the author, 1 vol. 8vo., 632 pages, now ready, 1850.
Churchill's Monographs of the Diseases of Females, 1 vol. 8vo., now ready, 450 pages.
Clymer and others on Fevers, a complete work in 1 vol. 8vo., 600 pages.
Day on Old Age, 1 vol. 8vo., 226 pages.
Dewees on Children, 9th ed., 1 vol. 8vo., 548 pp.
Dewees on Females, 9th ed., 1 vol. 8vo., 532 p. pls.
Dunglison's Practice of Medicine, 3d edition, 2 vols. 8vo., 1500 pages.
Esquirol on Insanity, by Hunt, 8vo., 496 pages.
Meigs' Letters on Diseases of Females, 1 vol. 8vo., 670 pages. A new work.
Meigs on Certain Diseases of Infancy, 1 vol. 8vo. A new work, preparing.
Thomson on the Sick Room, &c., 1 vol. large 12mo., 360 pages, cuts.
Watson's Principles and Practice of Physic, 3d edition by Condie, 1 vol. 8vo., 1060 large pages.
West's Lectures on the Diseases of Infancy and Childhood. 1 vol. 8vo., 452 pp.

SURGERY.

Brodie on Urinary Organs, 1 vol. 8vo., 214 pages.
Brodie on the Joints, 1 vol. 8vo., 216 pages.
Brodie's Lectures on Surgery, 1 vol. 8vo., 350 pp.
Brodie's Select Surgical Works, 780 pp. 1 vol. 8vo.
Chelius' System of Surgery, by South and Norris, in 3 large 8vo. vols., near 2200 pages.
Cooper on Dislocations and Fractures, 1 vol. 8vo., 500 pages, many cuts.
Cooper on Hernia, 1 vol. imp. 8vo., many plates.
Cooper on the Testis and Thymus Gland, 1 vol. imperial 8vo., many plates.
Cooper on the Anatomy and Diseases of the Breast, Surgical Papers, &c. &c., 1 vol. imp. 8vo., pl'ts.
Druitt's Principles and Practice of Modern Surgery, 1 vol. 8vo., 576 pages, 193 cuts, 4th ed.
Dufton on Deafness and Disease of the Ear, 1 vol. 12mo., 120 pages.
Durlacher on Corns, Bunions, &c., 12mo., 134 pp.

Fergusson's Practical Surgery, 1 vol. 8vo., 3d edition, 630 pages, 274 cuts.
Guthrie on the Bladder, 8vo., 150 pages.
Jones' Ophthalmic Medicine and Surgery, by Hays, 1 vol. 12mo., 529 pp., cuts and plates.
Liston's Lectures on Surgery, by Mütter, 1 vol. 8vo., 566 pages, many cuts.
Lawrence on the Eye, by Hays, new edition, much improved, 863 pages, many cuts & plates.
Lawrence on Ruptures, 1 vol. 8vo., 480 pages.
Miller's Principles of Surgery, 2d edition, 1 vol. 8vo., 538 pp., 1848.
Miller's Practice of Surgery, 1 vol. 8vo., 496 pp.
Malgaigne's Operative Surgery, by Brittan, with cuts. (Publishing in the Med. News and Lib.)
Maury's Dental Surgery, 1 vol. 8vo., 286 pages, many plates and cuts.
Robertson on the Teeth, 1 vol. 8vo., 230 pp., pts.
Sargent's Minor Surgery, 1 vol. royal 12mo., 380 pages, 128 cuts.

MATERIA MEDICA AND THERAPEUTICS.

Christison's and Griffith's Dispensatory, 1 large vol. 8vo., 216 cuts, over 1000 pages.
Carpenter on Alcoholic Liquors in Health and Disease, 1 vol. 12mo. (Just ready.)
Dunglison's Materia Medica and Therapeutics, now ready, 4th ed., much improved, with cuts, 2 vols. 8vo., 1850.
Dunglison on New Remedies, 5th ed., 1 vol. 8vo., 653 pages.
De Jongh on Cod-Liver Oil, 12mo.
Ellis' Medical Formulary, 9th ed., much improved, 1 vol. 8vo., 268 pages.
Griffith's Universal Formulary, 1 large vol., 8vo. 560 pages. (Now ready.)
Griffith's Medical Botany, a new work, 1 large vol. 8vo., 704 pp., with over 350 illustrations.
Mayne's Dispensatory, 1 vol. 12mo., 330 pages.
Mohr, Redwood, and Procter's Pharmacy, 1 vol. 8vo., 550 pages, 506 cuts.
Pereira's Materia Medica, by Carson, 2d ed., 2 vols. 8vo., 1580 large pages, 300 cuts.
Royle's Materia Medica and Therapeutics, by Carson, 1 vol. 8vo., 689 pages, many cuts.

OBSTETRICS.

Churchill's Theory and Practice of Midwifery, by Huston, 3d ed., 1 vol. 8vo., 526 pp., many cuts.
Dewees' Midwifery, 11th ed., 1 vol. 8vo., 660 pp., plates.
Lee's Clinical Midwifery, 12mo., 238 pages.
Meigs' Obstetrics; the Science and the Art; 1 vol. 8vo., 686 pages, 121 cuts.
Ramsbotham on Parturition, with many plates, 1 large vol. imperial 8vo., 520 pp. 5th edition.
Smith (Tyler) on Parturition, 1 vol. 12mo., 400 pp.

CHEMISTRY AND HYGIENE.

Bowman's Practical Chemistry, 1 vol. 12mo., 97 cuts, 350 pages.
Bowman's Handbook of Medical Chemistry, 1 vol. 12mo., many cuts, just ready.
Brigham on Excitement, &c., 1 vol. 12mo., 204 pp.
Dunglison on Human Health, 2d ed., 8vo., 464 pp.
Fowne's Elementary Chemistry for Students, 2d ed., 1 vol. royal 12mo., 460 pages, many cuts.
Gardner's Medical Chemistry, 1 vol. 12mo. 400 pp.
Griffith's Chemistry of the Four Seasons, 1 vol. royal 12mo., 451 pages, many cuts.
Knapp's Chemical Technology, by Johnson, 2 vols. 8vo., 936 pp., 460 large cuts.
Simon's Chemistry of Man, 8vo., 730 pp., plates.

MEDICAL JURISPRUDENCE, EDUCATION, &c.

Bartlett's Philosophy of Medicine, 1 vol. 8vo., 312 pages.
Bartlett on Certainty in Medicine, 1 vol. small 8vo., 84 pages.
Dunglison's Medical Student, 2d ed. 12mo., 312 pp.
Taylor's Medical Jurisprudence, by Griffith, 1 vol. 8vo., new and enlarged edition, 1850.
Taylor on Poisons, by Griffith, 1 vol. 8vo., 688 pp.
Traill's Medical Jurisprudence, 1 vol. 8vo., 234 pp.
Transactions of the American Medical Association, Vol. I. 8vo., 404 pp. Vol. II., 956 pp.

NATURAL SCIENCE, &c.

Arnott's Physics, 1 vol 8vo., 484 pp., many cuts.
Ansted's Ancient World, Popular Geology, in 1 12mo. volume, with numerous cuts, 382 pages.
Bird's Natural Philosophy, 1 vol. royal 12mo., 402 pages and 372 wood-cuts.
Brewster's Optics, 1 vol. 12mo. 423 pp. many cuts.
Broderip's Zoological Recreations, 1 vol. 12mo., pp. 376.
Coleridge's Idea of Life, 12mo., 94 pages.
Carpenter's Popular Vegetable Physiology, 1 vol. royal 12mo., many cuts.
Dana on Zoophytes, being vol. 8 of Ex. Expedition, royal 4to., extra cloth.
Atlas to "Dana on Zoophytes," im. fol., col. pl's.
Hale's Ethnography and Philology of the U. S. Exploring Expedition, in 1 large imp. 4to. vol.
Herschel's Treatise on Astronomy, 1 vol. 12mo., 417 pages, numerous plates and cuts.
Herschel's Outlines of Astronomy, 1 vol. small 8vo., plates and cuts. (A new work.) 620 pp.
Humboldt's Aspects of Nature, 1 vol. 12mo., new edition.
Johnston's Physical Atlas, 1 vol. imp. 4to., half bound, 25 colored maps.
Kirby on Animals, plates, 1 vol. 8vo., 520 pages.
Kirby and Spence's Entomology, 1 vol. 8vo., 600 large pages; plates plain or colored.
Müller's Physics and Meteorology, 1 vol. 8vo., 636 pp., with 540 wood-cuts and 2 col'd plates.
Roget's Animal and Vegetable Physiology, with 400 cuts, 2 vols. 8vo., 872 pages.
Small Books on Great Subjects, 12 parts, done up in 3 handsome 12mo. volumes, extra cloth.
Somerville's Physical Geography, 1 vol. 12mo., cloth, 540 pages, enlarged edition, now ready.
Weisbach's Mechanics applied to Machinery and Engineering, Vol. I. 8vo., 486 p. 550 wood-cuts Vol. II., 8vo., 400 pp., 340 cuts.

VETERINARY MEDICINE.

Clater and Skinner's Farrier, 1 vol. 12mo., 220 pp.
Youatt's Great Work on the Horse, by Skinner, 1 vol. 8vo., 448 pages, many cuts.
Youatt and Clater's Cattle Doctor, 1 vol. 12mo., 282 pages, cuts.
Youatt on the Dog, by Lewis, 1 vol. demy 8vo., 403 pages, beautiful plates.
Youatt on the Pig, a new work, with beautiful illustrations of all the different varieties, 12mo.

Neill and Smith's Compend of the Medical Sciences, 1 vol. large 12mo., 900 pages. 350 cuts.

MEDICAL BOOKS IN PRESS.

Barlow's Practice of Medicine. In one vol. 8vo. (Preparing.) Golding Bird's Therapeutics. (Preparing.) Carpenter's Principles of General and Comparative Physiology. In 1 large 8vo. vol., many cuts. (Preparing.) Stillé's General and Special Therapeutics. In one vol. 8vo (Preparing.) Todd and Bowman's Physiological Anatomy and Physiology of Man. (Three-fourths of this has been published in the Medical News and Library.) A complete work on the Structure and Diseases of the Ear. Malgaigne's Operative Surgery. In one vol. 8vo. (Publishing in the Medical News and Library.) De La Beche's Geology, with many illustrations. A new work on Popular Medicine, one vol. 8vo. A Cyclopedia of Anatomy and Physiology, based on the large work of Todd. Graham's Chemistry, by Bridges. 2d edition. much enlarged. One vol. 8vo., several hundred cuts. Meigs on some of the more important diseases of Infants, (nearly ready.) Longet's Treatise on Physiology, 2 vols. 8vo., translated by Smith, (preparing). Together with other new and important works.

LIBRARY OF SURGICAL KNOWLEDGE.

A SYSTEM OF SURGERY.

BY J. M. CHELIUS,

Doctor of Medicine and Surgery, Public Professor of General and Ophthalmic Surgery, &c. &c. in the University of Heidelberg.

TRANSLATED FROM THE GERMAN,
AND ACCOMPANIED WITH ADDITIONAL NOTES AND REFERENCES,

BY JOHN F. SOUTH,

Surgeon to Saint Thomas' Hospital.

Complete in three very large octavo volumes of nearly 2200 pages, strongly bound, with raised bands and double titles: or in seventeen numbers, at fifty cents each.

We now cordially congratulate him (Dr. South) on the completion of his task, and, as a whole, on the mode in which he has fulfilled it. Mr. South's ambition, however, was not limited to the production of a mere translation of his author, with the addition of such occasional notes as might render the handbook more acceptable to the English student; but he aimed at the higher object of supplying what he truly observes has been a desideratum for some time past in English surgical literature, a complete "System of Surgery," suited to the wants of the practitioner, and worthy of the country and language in which it is written. In achieving this end, the character of the work as it appeared in German, and the purpose for which it was published, have been in a great degree sacrificed; and we scarcely anticipate that the present "System" will ever become the manual of the student, who, for the most part, prefers more succinct descriptions of disease. and a more dogmatic style. This, however, is not a subject of regret, for there was no lack of "Outlines" and "Compendiums," which fully answer the purpose for which they were written; and we are therefore better pleased to welcome the work in its existing form.

It will be impracticable to give anything like a satisfactory analysis of the whole of Mr. South's copious work: we shall, therefore, content ourselves with laying before our readers an outline of the contents and arrangement of the volumes before us, selecting, in passing, certain divisions or chapters, as subject-matter for especial comment.

To those who are familiar with the manual of Chelius in the original. the comparative bulk of Mr. South's translation will at once convey a just impression of the copious introduction of new matter into the English version. The plan adopted is this: The text of the original is printed in a larger type, with numerical headings to the paragraphs. The introduced matter consists of quotations, all of which have their appropriate references, and of the results of the translator's own experience. This is printed in a smaller type. and included between brackets, Mr. South's own opinions being further distinguished by the insertion of his initials at the close of the paragraphs containing them. There are, further, other occasional paragraphs, likewise printed in a smaller type, which constitute part of the original work, where they also appear under the same distinguished form. These, when they exist. immediately follow the principal text, and are not contained between brackets.

The arrangement of the work is based on scientific principles, and its contents are comprised under the following eight divisions: 1, Inflammation; 2. Diseases which result from the Disturbance of Physical Continuity; 3. Diseases dependent on Unnatural Coherence; 4. Diseases dependent on the Presence of Foreign Bodies; 5, Diseases which consist in the Degeneration of Organic Parts. or in the Production of New Structures; 6. Loss of Organic Parts; 7. Superfluity of Organic Parts; 8, The Elementary Proceedings of Surgical Operations. These are preceded by a brief introduction, a historical sketch of Surgery, and a copious table of its general literature.

Of the arrangement of the work we cannot but approve, and think it judicious of Mr. South not to have interfered with the plan selected by his author. The annotations and additions evince infinite research and great judgment. The translator enters entirely into the spirit of his author, and we should say that there is much that is congenial in their cast of mind; leaning, in surgical practice, rather to the cautious than to the heroic The tabular views of operations. especially of stone cases. are valuable and interesting in a statistical point of view. A very copious index is appended to the work, which of course greatly enhances the value of so voluminous a treatise. On the whole, we feel gratified with, and proud of, the work in its English garb; and we do not hesitate to pronounce it the best and most comprehensive system of modern surgery with which we are acquainted, and as such we earnestly recommend it to the student and practitioner.—*Medico-Chirurgical Review.*

The fullest and ablest digest extant of all that relates to the present advanced state of Surgical Pathology.—*American Medical Journal.*

If we were confined to a single work on Surgery, that work should be Chelius's.—*St. Louis Med. Journal.*

As complete as any system of Surgery can well be.—*Southern Medical and Surgical Journal.*

The most finished system of Surgery in the English language.—*Western Lancet*

The most learned and complete systematic treatise now extant.—*Edinburgh Medical Journal.*

No work in the English language comprises so large an amount of information relative to operative medicine and surgical pathology.—*Medical Gazette.*

A complete encyclopedia of surgical science—a very complete surgical library—by far the most complete and scientific system of surgery in the English language.—*N. Y. Journal of Medicine.*

One of the most complete treatises on Surgery in the English language —*Monthly Journal of Med. Science.*

The most extensive and comprehensive account of the art and science of Surgery in our language.—*Lancet.*

A TREATISE ON DISEASES OF THE BONES.

BY EDWARD STANLEY, F. R. S.,

President of the Royal College of Surgeons of England, and Surgeon to St Bartholomew's Hospital.

In one neat octavo volume, extra cloth, of 286 pages.

A work which every medical or surgical pathologist must consult.—*London Medical Gazette.*

Peculiarly well adapted for practical reference as well as for closet meditation.—*American Med. Journal.*

We scarcely know of a more useful and important work It should be in every surgeon's hands, and the general practitioner of medicine would receive gratifying assistance from it.—*Boston Med. and Surg. Journal.*

A more acceptable offering could not have been made to the medical profession, than this excellent treatise on the diseases of the bones. A philosophical monograph on this subject was needed, and we are thankful that the duty of preparing it devolved upon Mr. Stanley.

We are reluctantly compelled to close the analysis of this admirable work. at the very threshold of some of the most important subjects. In many points of view, we regard Mr. Stanley's "Treatise on the Diseases of the Bones" as the most valuable contribution to surgery we have seen for years, and we desire to make our readers as familiar with its revelations as a full analysis can make them.—*The Western Journal of Medicine and Surgery*

MACLISE'S SURGICAL ANATOMY.—Continued.

From Prof. Alden Marsh, Albany, N. Y.

From what I have seen of it. I think the design and execution of the work admirable, and, at the proper time in my course of lectures, I shall exhibit it to the class, and give it a recommendation worthy of its great merit.

From H. H. Smith, M. D, Philadelphia.

Permit me to express my gratification at the execution of Maclise's Surgical Anatomy. The plates are, in my opinion, the best lithographs that I have seen of a medical character, and the coloring of this number cannot, I think, be improved. Estimating highly the contents of this work, I shall continue to recommend it to my class as I have heretofore done.

From Prof. D. Gilbert, Philadelphia.

Allow me to say, gentlemen, that the thanks of the profession at large, in this country, are due to you for the republication of this admirable work of Maclise. The precise relationship of the organs in the regions displayed is so perfect, that even those who have daily access to the dissecting room may, by consulting this work, enliven and confirm their anatomical knowledge prior to an operation. But it is to the thousands of practitioners of our country, who cannot enjoy these advantages, that the perusal of those plates, with their concise and accurate descriptions, will prove of infinite value. These have supplied a desideratum, which will enable them to refresh their knowledge of the important structures involved in their surgical cases, thus establishing their self-confidence, and enabling them to undertake operative procedures with every assurance of success. And as all the practical departments in medicine rest upon the same basis, and are enriched from the same sources, I need hardly add that this work should be found in the library of every practitioner in the land.

From Professor J. M. Bush, of Lexington, Ky.

I am delighted with both the plan and execution of the work, and shall take all occasions to recommend it to my private pupils and public classes.

The most accurately engraved and beautifully colored plates we have ever seen in an American book—one of the best and cheapest surgical works ever published.—*Buffalo Medical Journal.*

It is very rare that so elegantly printed, so well illustrated, and so useful a work, is offered at so moderate a price.—*Charleston Medical Journal.*

A work which cannot but please the most fastidious lover of surgical science, and we hesitate not to say that if the remaining three numbers of this work are in keeping with the present, it cannot fail to give universal satisfaction. In it, by a succession of plates, are brought to view the relative anatomy of the parts included in the important surgical divisions of the human body, with that fidelity and neatness of touch which is scarcely excelled by nature herself. The part before us differs in many respects from anything of the kind which we have ever seen before. While we believe that nothing but an extensive circulation can compensate the publishers for the outlay in the production of this edition of the work—furnished as it is at a very moderate price, within the reach of *all*—we desire to see it have that circulation which the zeal and peculiar skill of the author (he being his own draughtsman), the utility of the work, and the neat style with which it is executed should demand for it in a liberal profession.—*N. Y. Journal of Medicine.*

This is an admirable reprint of a deservedly popular London publication. Its English prototype, although not yet completed, has already won its way, amongst our British brethren, to a remarkable success. Its plates can boast a superiority that places them almost beyond the reach of competition. And we feel too thankful to the Philadelphia publishers for their very handsome reproduction of the whole work, and at a rate within everybody's reach, not to urge all our medical friends to give it, for their own sakes, the cordial welcome it deserves, in a speedy and extensive circulation.—*The Medical Examiner.*

The plates are accompanied by references and explanations, and when the whole has been published it will be a complete and beautiful system of Surgical Anatomy, having an advantage which is important, and not possessed by colored plates generally, viz: its cheapness, which places it within the reach of every one who may feel disposed to possess the work. Every practitioner, we think, should have a work of this kind within reach, as there are many operations requiring immediate performance in which a book of reference will prove most valuable.—*Southern Medical and Surg. Journal.*

The work of Maclise on Surgical Anatomy is of the highest value. In some respects it is the best publication of its kind we have seen, and is worthy of a place in the library of any medical man, while the student could scarcely make a better investment than this.—*The Western Journal of Medicine and Surgery.*

No such lithographic illustrations of surgical regions have hitherto, we think, been given. While the operator is shown every vessel and nerve where an operation is contemplated, the exact anatomist is refreshed by those clear and distinct dissections which every one must appreciate who has a particle of enthusiasm. The English medical press has quite exhausted the words of praise, in recommending this admirable treatise. Those who have any curiosity to gratify, in reference to the perfectibility of the lithographic art in delineating the complex mechanism of the human body, are invited to examine our specimen copy. If anything will induce surgeons and students to patronize a book of such rare value, and everyday importance to them it will be a survey of the artistical skill exhibited in these fac-similes of nature.—*Boston Med. and Surg. Journal.*

The fidelity and accuracy of the plates reflect the highest credit upon the anatomical knowledge of Mr. Maclise. We strongly recommend the descriptive commentaries to the perusal of the student both of surgery and medicine. These plates will form a valuable acquisition to practitioners settled in the country whether engaged in surgical, medical, or general practice.—*Edinburgh Medical and Surgical Journal.*

We are well assured that there are none of the cheaper, and but few of the more expensive works on anatomy, which will form so complete a guide to the student or practitioner as these plates. To practitioners, in particular, we recommend this work as far better, and not at all more expensive, than the heterogeneous compilations most commonly in use, and which, whatever their value to the student preparing for examination, are as likely to mislead as to guide the physician in physical examination, or the surgeon in the performance of an operation.—*Monthly Journal of Medical Sciences*

The dissections from which these various illustrations are taken, appear to have been made with remarkable success; and they are most beautifully represented. The surgical commentary is pointed and practical. We know of no work on surgical anatomy which can compete with it.—*Lancet.*

A NEW MINOR SURGERY.

ON BANDAGING, AND OTHER POINTS OF MINOR SURGERY.

BY F. W. SARGENT, M. D.

In one handsome royal 12mo. volume of nearly 400 pages, with 128 wood-cuts.

From Professor Gilbert, Philadelphia.

Embracing the smaller details of surgery, which are illustrated by very accurate engravings, the work becomes one of very great importance to the practitioner in the performance of his daily duties, since such information is rarely found in the general works on surgery now in use.

From Professor Peaslee, Brunswick, Maine

While abroad I had consulted all the works which have been published on these subjects, and I feel myself constrained to say that your book contains all the excellences to be found in all of them together, besides many others not to be found in any of them, though you have not made, after all, a large book.

LISTON & MUTTER'S SURGERY.

LECTURES ON THE OPERATIONS OF SURGERY, AND ON DISEASES AND ACCIDENTS REQUIRING OPERATIONS.

DELIVERED AT UNIVERSITY COLLEGE, LONDON,

BY ROBERT LISTON, ESQ., F. R. S., &c.

EDITED, WITH NUMEROUS ADDITIONS AND ALTERATIONS,

BY T. D. MÜTTER, M. D.,

Professor of Surgery in the Jefferson Medical College of Philadelphia.

In one large and handsome octavo volume of 566 *pages, with* 216 *wood-cuts.*

About two hundred and fifty pages in this work are contributed by Dr. Mütter, presenting the results of his great experience, and adapting the whole to the wants of the American physician and surgeon. Among the additions of Dr. M. will be found full and elaborate essays on Staphyloraphy, the various Plastic Operations, Club-foot, Affections of the Eye, Deformities arising from Burns, and many other important subjects not to be met with in so complete a form in perhaps any other accessible work. The great reputation of both the authors connected with the work, and the thorough manner in which it is illustrated, should command for it the universal attention of the profession.

"It is a compendium of the modern practice of Surgery as complete and accurate as any treatise of similar dimensions in the English language."—*Western Lancet.*

LIBRARY OF OPHTHALMIC MEDICINE AND SURGERY.

A TREATISE ON THE DISEASES OF THE EYE.

BY W LAWRENCE, F. R. S.,

Surgeon Extraordinary to the Queen. Surgeon to St Bartholomew's Hospital, &c. &c.

A NEW EDITION.

With many Modifications and Additions, and the introduction of nearly two hundred Illustrations.

BY ISAAC HAYS, M. D.

In one very large 8vo. vol. of 860 pages, with twelve plates and many wood-cuts through the text.

JONES ON THE EYE.

THE PRINCIPLES AND PRACTICE OF OPHTHALMIC MEDICINE AND SURGERY.

BY T. WHARTON JONES, F. R. S., &c. &c.

EDITED BY ISAAC HAYS, M. D., &c.

In one very neat volume, large royal 12mo. of 529 pages, with four plates, plain or colored, and ninety-eight well executed wood-cuts.

BRODIE'S SURGICAL LECTURES.—Clinical Lectures on Surgery. 1 vol. 8vo., cloth. 350 pp.

BRODIE ON THE JOINTS.—Pathological and Surgical Observations on the Diseases of the Joints. 1 vol. 8vo., cloth. 216 pp.

BRODIE ON URINARY ORGANS.—Lectures on the Diseases of the Urinary Organs. 1 vol. 8vo., cloth. 214 pp.

*** These three works may be had neatly bound together, forming a large volume of "Brodie's Surgical Works." 780 pp.

RICORD ON VENEREAL. A Practical Treatise on Venereal Diseases. With a Therapeutical Summary and Special Formulary. Translated by Sidney Doane, M. D Fourth edition. 1 vol. 8vo. 340 pp

COOPER (SIR ASTLEY) ON THE ANATOMY AND TREATMENT OF ABDOMINAL HERNIA. 1 large vol., imp. 8vo., with over 130 lithographic figures.

COOPER ON THE STRUCTURE AND DISEASES OF THE TESTIS, AND ON THE THYMUS GLAND. 1 vol., imp. 8vo., with 177 figures on 29 plates.

COOPER ON THE ANATOMY AND DISEASES OF THE BREAST, WITH TWENTY-FIVE MISCELLANEOUS AND SURGICAL PAPERS. 1 large vol., imp. 8vo., with 252 figures on 36 plates.

COOPER ON DISLOCATIONS AND FRACTURES OF THE JOINTS.—Edited by Bransby Cooper and J. C. Warren. 1 vol. 8vo., with 133 cuts. 500 pp.

DURLACHER ON CORNS, BUNIONS, &c.—A Treatise on Corns, Bunions, the Diseases of Nails, and the General Management of the Feet In one 12mo. volume, cloth. 134 pp

GUTHRIE ON THE BLADDER, &c.—The Anatomy of the Bladder and Urethra, and the Treatment of the Obstructions to which those Passages are liable. In one vol. 8vo. 150 pp.

LAWRENCE ON RUPTURES.—A Treatise on Ruptures, from the fifth London Edition. In one 8vo. vol. sheep. 480 pp.

MAURY'S DENTAL SURGERY.—A Treatise on the Dental Art, founded on Actual Experience. Illustrated by 241 lithographic figures and 54 wood-cuts. Translated by J. B. Savier. In 1 8vo. vol., sheep. 286 pp

ROBERTSON ON THE TEETH.—A Practical Treatise on the Human Teeth, with Plates. One small volume, 8vo. 230 pp.

DUFTON ON THE EAR.—The Nature and Treatment of Deafness and Diseases of the Ear; and the Treatment of the Deaf and Dumb. One small 12mo. volume. 120 pp.

MALGAIGNE'S SURGERY.—Operative Surgery, translated, with Notes, by Brittan. With wood-cuts. (Now publishing in the "Medical News and Library.")

SHARPEY AND QUAIN'S ANATOMY. Just Issued.

HUMAN ANATOMY.

BY JONES QUAIN, M.D.

FROM THE FIFTH LONDON EDITION.

EDITED BY

RICHARD QUAIN, F.R.S.,

AND

WILLIAM SHARPEY, M.D., F.R.S.,

Professors of Anatomy and Physiology in University College, London.

REVISED, WITH NOTES AND ADDITIONS,

BY JOSEPH LEIDY, M. D.

Complete in Two large Octavo Volumes, of about Thirteen Hundred Pages.

BEAUTIFULLY ILLUSTRATED

With over Five Hundred Engravings on Wood.

We have here one of the best expositions of the present state of anatomical science extant. There is not probably a work to be found in the English language which contains so complete an account of the progress and present state of general and special anatomy as this. The descriptions which it contains are remarkably clear and explicit. The American editor has done his task with credit, and a glance at the typographical execution of the work will show that its enterprising publishers have acted their part well in this respect; and in presenting to the American profession this edition, have placed us all under lasting obligations. By the anatomist this work must be eagerly sought for, and no student's library can be complete without it.—*The N. Y. Journal of Medicine.*

We know of no work which we would sooner see in the hands of every student of this branch of medical science than Sharpey and Quain's Anatomy.—*The Western Journal of Medicine and Surgery.*

It may now be regarded as the most complete and best posted up work on anatomy in the language. It will be found particularly rich in general anatomy.

The minute structure of bone is described and delineated most clearly and beautifully; in neither will this compare unfavorably with any work we have; and the delineations, for variety of detail, will be found to excel those even of Todd and Bowman.

The whole work shows the utmost care in preparation and most thorough knowledge of the subject, and it cannot fail to assume a leading position among anatomical works. We would recommend it to students, particularly on account of the general anatomy or histology prefixed to the special description of each system.—*The Charleston Medical Journal.*

We have often had occasion to express our great indebtedness to Messrs. Lea & Blanchard, the most distinguished of American Medical publishers, for the many valuable works which they have so repeatedly and liberally supplied us. On no one occasion do we feel more thankful to them than in receiving Sharpey and Quain's Anatomy. We believe we express the opinion of all who have examined these volumes, that there is no work superior to them on the subject which they so ably describe—the minute structure of the human body. We cannot commend it too highly to the patronage of the profession.—*Southern Medical and Surgical Journal.*

Since that time, a close inspection of the work has revealed new beauties and objects of worth; its perusal has been a pleasant task, and we can only reiterate a former assertion, that it is one of the most comprehensive and best works upon anatomy in the English language. It is equally valuable to the teacher, practitioner, and student in medicine, and to the surgeon in particular, it is welcome, by presenting in a masterly style the surgical anatomy of the most important regions of the body.

The American Editor has enhanced the value of the original work. Besides contributing largely to the microscopical anatomy of almost every texture treated on, he has added much that is useful to its special anatomy and physiology.—*The Ohio Medical and Surgical Journal.*

To those who wish an extensive treatise on Anatomy, we recommend these handsome volumes as the best that have ever issued from the English or American Press.

As a full and systematic work on Anatomy, we apprehend that Quain and Sharpey's Anatomy will come to be regarded as superior to anything that has preceded it.—*The N. W. Medical and Surgical Journal.*

We believe that any country might safely be challenged to produce a treatise on anatomy so readable, so clear, and so full upon all important topics.—*British and Foreign Medico-Chirurgical Review.*

It is indeed a work calculated to make an era in anatomical study, by placing before the student every department of his science, with a view to the relative importance of each; and so skillfully have the different parts been interwoven, that no one who makes this work the basis of his studies will hereafter have any excuse for neglecting or undervaluing any important particulars connected with the structure of the human frame; and whether the bias of his mind lead him in a more especial manner to surgery, physic, or physiology, he will find here a work at once so comprehensive and practical as to defend him from exclusiveness on the one hand, and pedantry on the other.—*Monthly Journal and Retrospect of the Medical Sciences.*

In general, descriptive, and surgical anatomy, it contains all the information which a student can desire.—*London Medical Gazette.*

We have no hesitation in recommending this treatise on anatomy as the most complete on that subject in the English language; and the only one, perhaps, in any language, which brings the state of knowledge forward to the most recent discoveries.—*The Edinburgh Medical and Surgical Journal.*

One of the most valuable works to which the medical student can apply for assistance in the prosecution of his studies.—*Medico-Chirurgical Review.*

Admirably calculated to fulfil the object for which it is intended.—*Provincial Medical Journal.*

The most complete Treatise on Anatomy in the English language.—*Edinburgh Medical Journal.*

There is no work in the English language to be preferred to Dr. Quain's Elements of Anatomy.—*London Journal of Medicine.*

THE STUDENT'S TEXT-BOOK OF ANATOMY.
NEW AND IMPROVED EDITION—JUST ISSUED.

A SYSTEM OF HUMAN ANATOMY,
GENERAL AND SPECIAL.

BY ERASMUS WILSON, M. D.

FOURTH AMERICAN FROM THE LAST ENGLISH EDITION.

EDITED BY PAUL B. GODDARD, A. M., M. D.

WITH TWO HUNDRED AND FIFTY ILLUSTRATIONS.

Beautifully printed, in one large octavo volume of nearly six hundred pages.

In many, if not all the Colleges of the Union, it has become a standard text-book. This, of itself, is sufficiently expressive of its value. A work very desirable to the student; one, the possession of which will greatly facilitate his progress in the study of Practical Anatomy.—*New York Journal of Medicine.*

Its author ranks with the highest on Anatomy.—*Southern Medical and Surgical Journal.*

It offers to the student all the assistance that can be expected from such a work.—*Medical Examiner.*

The most complete and convenient manual for the student we possess.—*American Journal of Med. Science.*

In every respect this work, as an anatomical guide for the student and practitioner, merits our warmest and most decided praise.—*London Medical Gazette.*

HORNER'S ANATOMY.

SPECIAL ANATOMY AND HISTOLOGY.

BY WILLIAM E. HORNER, M. D.,
Professor of Anatomy in the University of Pennsylvania, &c. &c.

SEVENTH EDITION.

With many improvements and additions. In two 8vo. vols. of 1130 pages, with illustrations on wood.

It is altogether unnecessary now to inquire into the particular merits of a work which has been so long before the profession, and is so well known as the present one; but in announcing a new edition, it is proper to state that it has undergone several modifications, and has been much extended, so as to place it on a level with the existing advanced state of anatomy. The histological portion has been remodelled and rewritten since the last edition; numerous wood-cuts have been introduced, and specific references are made throughout the work to the beautiful figures in the Anatomical Atlas, by Dr. H. H. Smith.—*The American Medical Journal.*

NEW AND CHEAPER EDITION OF

SMITH & HORNER'S ANATOMICAL ATLAS.

AN ANATOMICAL ATLAS,
ILLUSTRATIVE OF THE STRUCTURE OF THE HUMAN BODY.

BY HENRY H. SMITH, M. D., &c.

UNDER THE SUPERVISION OF

WILLIAM E. HORNER, M.D.,
Professor of Anatomy in the University of Pennsylvania.

In one large octavo volume, with about six hundred and fifty beautiful figures.

With the view of extending the sale of this beautifully executed and complete "Anatomical Atlas," the publishers have prepared a new edition, printed on both sides of the page, thus materially reducing its cost, and enabling them to present it at a price about forty per cent. lower than former editions, while, at the same time, the execution of each plate is in no respect deteriorated, and not a single figure is omitted.

These figures are well selected, and present a complete and accurate representation of that wonderful fabric, the human body. The plan of the Atlas, which renders it peculiarly convenient for the student, and its superb artistical execution, have been already pointed out. We must congratulate the student upon the completion of this Atlas, as it is the most convenient work of the kind that has yet appeared; and we must add, that the very beautiful manner in which it is "got up" is so creditable to the country as to be flattering to our national pride.—*American Medical Journal.*

WILSON'S DISSECTOR; OR, PRACTICAL AND SURGICAL ANATOMY.

BY ERASMUS WILSON, M. D.,

Modified and re-arranged by PAUL B. GODDARD, M. D.

In one volume, royal 12mo., of four hundred and forty pages, with 106 wood-cuts.

HORNER'S DISSECTOR.

THE UNITED STATES DISSECTOR;

Being a new edition, with extensive modifications, and almost re-written, of

"HORNER'S PRACTICAL ANATOMY."

In one very neat volume, royal 12mo., of 440 pages, with many illustrations on wood.

NEW AND MUCH IMPROVED EDITION, to 1850.—Now Ready.

CARPENTER'S HUMAN PHYSIOLOGY.

PRINCIPLES OF HUMAN PHYSIOLOGY,

WITH THEIR CHIEF APPLICATIONS TO

PATHOLOGY, HYGIENE, AND FORENSIC MEDICINE.

BY WILLIAM B. CARPENTER, M. D., F. R. S., &c.

FOURTH AMERICAN EDITION,

With extensive Additions and Improvements by the Author.

With Two Lithographic Plates, and 304 wood-cuts.

In one large and handsomely printed octavo volume of over seven hundred and fifty pages.

In preparing a new edition of this very popular text-book. the publishers have had it completely revised by the author, who, without materially increasing its bulk, has embodied in it all the recent investigations and discoveries in physiological science, and has rendered it in every respect on a level with the improvements of the day. Although the number of the wood-engravings has been but little increased, a considerable change will be found, many new and interesting illustrations having been introduced in place of others which were considered of minor importance, or which the advance of science had shown to be imperfect, while the plates have been altered and redrawn under the supervision of the author by a competent London artist. In passing the volume through the press in this country, the services of a professional gentleman have been secured, in order to insure the accuracy so necessary to a scientific work. Notwithstanding these improvements, the price of the volume is maintained at its former moderate rate.

From Professor W. R. Grant, of Philadelphia.

The works of Dr Carpenter in general, and this in particular, I consider of the highest authority. From the first I have recommended it to our students as one of the best works published on the subject. The present edition, in particular, I consider worthy the attention not only of the medical student, but of the whole profession.

From Professor O. W. Holmes, of Boston.

I shall therefore be able now to recommend it to my class without the reservations which I was obliged to make when speaking of the former editions. It now constitutes an admirable digest of the science of physiology, and as such I shall speak of it to the pupils of the public and private medical schools with which I am connected.

From Professor R. S. Holmes, of St. Louis.

There is no text-book on the science, that I know of, to compare with it.

From Professor G. L. Collins, of Providence.

I have for several years used no other as a text-book for students. I shall continue to recommend it as the very best physiological work extant. I know that it has the approbation of all the physicians of this city.

From Professor Charles Hooker, of Yale College.

For years I have used Carpenter's Physiology as a text-book for my classes, considering it decidedly preferable to any other work on the subject. The original researches of Dr. Carpenter render his treatise indispensable to the members of the medical profession who wish to acquire a thorough knowledge of the fundamental principles of the science. The profession should regard themselves as under obligations to you for the successive editions of this excellent work.

From Professor L. A. Dugas, of Augusta, Georgia.

Dr. Carpenter's invaluable "Principles of Human Physiology" is a work that I prize very highly, and take great pleasure in recommending as a text-book to the class of the Medical College of Georgia. Its intrinsic merits alone, however, should secure for it a place in the library of every accomplished physician.

In this volume of Dr. Carpenter's, we need only say we have the well-ascertained facts, doctrines, &c. of the present period fully stated: for the known reputation of the previous editions of the work have been sufficient, alone, to command for it a ready and extensive sale.

We perceive, also, that there are many new illustrations added to this edition, which, to say the least, facilitate the learner, and render it admirably adapted to the end designed, a comprehensive and accurate work for the use of both student and practitioner —*N. Y. Journal of Medicine.*

CARPENTER'S ELEMENTS.

ELEMENTS OF PHYSIOLOGY,

Including Physiological Anatomy.—For the use of the Medical Student.

BY WILLIAM B. CARPENTER, M. D., F. R. S.,

Fullerian Professor of Physiology in the Royal Institution of Great Britain, &c.

With one hundred and eighty Illustrations.

In one 8vo. vol. of 566 pages, elegantly printed, to match his "Principles of Human Physiology."

The author has shown singular skill in preserving so marked a line of distinction between the present Manual and the "Principles of Physiology" previously published by him. They are both on precisely the same subject; but the one is neither a copy, nor an abstract, nor an abridgment of the other. In one thing, however, they are exactly alike—in their general excellence, and in their perfect adaptation to their respective purposes —*British and Foreign Medical Review.*

LONGET'S PHYSIOLOGY.—Preparing.

A TREATISE ON PHYSIOLOGY.

BY F. A. LONGET, M. D.

TRANSLATED FROM THE FRENCH, WITH NOTES AND ADDITIONS, BY FRANCIS GURNEY SMITH, M. D., Lecturer on Physiology in the Philadelphia Association for Medical Instruction, &c.

In two large octavo volumes, with numerous illustrations.

The profession in this country will doubtless welcome this work of the celebrated teacher, M Longet, as giving them the views of one who is universally held as one of the highest authorities in Physiology, while at the same time it presents a full and complete treatise on this extensive subject, thoroughly brought up to the most advanced state of science.

DUNGLISON'S HUMAN PHYSIOLOGY.

HUMAN PHYSIOLOGY.

WITH THREE HUNDRED AND SEVENTY ILLUSTRATIONS.

BY ROBLEY DUNGLISON, M. D.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE JEFFERSON MEDICAL COLLEGE, PHILADELPHIA, ETC. ETC.

SIXTH EDITION, GREATLY IMPROVED.

In two large octavo volumes, containing nearly 1350 pages.

Notwithstanding the numerous treatises which have appeared, during the last few years on this important subject, the work of Dr. Dunglison maintains its position as one of the fullest and most complete systems of physiology accessible to the profession in this country. As new editions are continually and frequently demanded, and as the author spares neither care nor exertion to keep each successive impression fully up to the most advanced state of science, the student may always rely upon being able to procure an edition containing the most recent investigations and discoveries.

It has long since taken rank as one of the medical classics of our language. To say that it is by far the best text-book of physiology ever published in this country, is but echoing the general testimony of the profession.—*N. Y. Journal of Medicine.*

The most full and complete system of Physiology in our language.—*Western Lancet.*

The most complete and satisfactory system of Physiology in the English language.—*Amer. Med Journal.*

The best work of the kind in the English language.—*Silliman's Journal.*

We have, on two former occasions, brought this excellent work under the notice of our readers, and we have now only to say that, instead of failing behind in the rapid march of physiological science, each edition brings it nearer to the van.—*British and Foreign Medical Review.*

A review of such a well-known work would be out of place at the present time. We have looked over it, and find, what we knew would be the case, that Dr. Dunglison has kept pace with the science to which he has devoted so much study, and of which he is one of the living ornaments. We recommend the work to the medical student as a valuable text-book, and to all inquirers into Natural Science, as one which will well and delightfully repay perusal.—*The New Orleans Medical and Surgical Journal.*

COMPENDIUM OF MULLER'S PHYSIOLOGY.—Lately Issued.

A MANUAL OF PHYSIOLOGY,

FOR THE USE OF STUDENTS.

BY WILLIAM SENHOUSE KIRKES, M. D.,

ASSISTED BY JAMES PAGET,

Lecturer on General Anatomy and Physiology in St. Bartholomew's Hospital.

In one handsome volume, royal 12mo., of 550 pages, with 118 wood-cuts.

This is, certainly, a most able manual of Physiology. The student will find in it, not a meagre outline, a bare skeleton of the leading particulars embraced in the science, but a very complete and accurate—though, at the same time, concise—account of the facts and generally admitted principles of Physiology; forming an admirable introduction to the study of that science, as well as a useful compendium for consultation by those who are preparing for an examination. The whole of the illustrations are very excellent, and calculated to render the description of the objects they represent clear and precise. To those who stand in need of a Manual of Physiology—and works of this description have now become, in a certain sense, indispensable portions of the apparatus of study—we can very confidently recommend the present one as well for its comprehensiveness as for its general accuracy.—*American Journal of the Medical Sciences.*

An excellent work, and for students one of the best within reach.—*Boston Medical and Surgical Journal.*

One of the best little books on Physiology which we possess.—*Braithwaite's Retrospect.*

Particularly adapted to those who desire to possess a concise digest of the facts of Human Physiology.—*British and Foreign Med.-Chirurg. Review.*

One of the best treatises which can be put into the hands of the student.—*London Medical Gazette.*

We conscientiously recommend it as an admirable "Handbook of Physiology."—*London Jour. of Medicine*

SOLLY ON THE BRAIN.

THE HUMAN BRAIN; ITS STRUCTURE, PHYSIOLOGY, AND DISEASES.

WITH A DESCRIPTION OF THE TYPICAL FORM OF THE BRAIN IN THE ANIMAL KINGDOM.

BY SAMUEL SOLLY, F. R. S., &c.,

Senior Assistant Surgeon to the St. Thomas' Hospital, &c.

From the Second and much Enlarged London Edition. In one octavo volume, with 120 *Wood-cuts.*

HARRISON ON THE NERVES.—An Essay towards a correct theory of the Nervous System. In one octavo volume, 292 pages.

MATTEUCCI ON LIVING BEINGS.—Lectures on the Physical Phenomena of Living Beings. Edited by Pereira. In one neat royal 12mo. volume, extra cloth, with cuts—388 pages.

ROGET'S PHYSIOLOGY.—A Treatise on Animal and Vegetable Physiology, with over 400 illustrations on wood. In two octavo volumes, cloth.

ROGET'S OUTLINES.—Outlines of Physiology and Phrenology. In one octavo volume, cloth—516 pages.

ON THE CONNECTION BETWEEN PHYSIOLOGY AND INTELLECTUAL SCIENCE. In one 12mo. volume, paper, price 25 cents.

TODD & BOWMAN'S PHYSIOLOGY.—Physiological Anatomy and Physiology of Man. With numerous handsome wood-cuts. Three-fourths of this work have appeared in the Medical News and Library; the conclusion may be expected this year, when those who have the commencement will be enabled to procure the completion.

WILLIAMS' PRINCIPLES—New and Enlarged Edition.

PRINCIPLES OF MEDICINE;

Comprising General Pathology and Therapeutics,

AND A BRIEF GENERAL VIEW OF

ETIOLOGY, NOSOLOGY, SEMEIOLOGY, DIAGNOSIS, PROGNOSIS, AND HYGIENICS.

BY CHARLES J. B. WILLIAMS, M. D., F. R. S.,

Fellow of the Royal College of Physicians, &c.

EDITED, WITH ADDITIONS, BY MEREDITH CLYMER, M. D.,

Consulting Physician to the Philadelphia Hospital, &c. &c.

THIRD AMERICAN, FROM THE SECOND AND ENLARGED LONDON EDITION.

In one volume, octavo, of 440 pages.

The best exposition in our language, or, we believe, in any language, of Rational Medicine, in its present improved and rapidly improving state.—*British and Foreign Medico-Chirurg. Review.*

We recommend every part of Dr. Williams' excellent Principles of Pathology to the diligent perusal of every physician who is not familiar with the accessions which have been made to medical science within the last few years.—*Western Journal of Medicine and Surgery.*

From Professor Thayer, of Boston.

It fills the place for which it was intended better than any other work.

From Professor S. H Dickson, of New York.

I shall be truly glad to know that a copy of it is in the hands of every member of our profession. As a public teacher, I know not how I could dispense with it.

MANUALS ON THE BLOOD AND URINE:

CONSISTING OF

I. A Practical Manual, containing a description of the General, Chemical, and Microscopical Characters of the Blood and Secretions of the Human Body, as well as of their compounds, including both their healthy and diseased states; with the best method of separating and estimating their ingredients. Also, a succinct account of the various concretions occasionally found in the body, and forming calculi. BY JOHN WILLIAM GRIFFITH, M. D., F. L. S., &c.

II. On the Analysis of the Blood and Urine in health and disease, and on the treatment of Urinary diseases. BY G. OWEN REESE, M. D., F. R. S., &c. &c.

III. A guide to the examination of the Urine in health and disease, for the use of students. BY ALFRED MARKWICK.

The whole forming one large royal 12mo. volume, of four hundred and sixty pages,

WITH ABOUT ONE HUNDRED FIGURES ON FIVE PLATES.

COPLAND ON PALSY.—Just Ready.

OF THE CAUSES, NATURE, AND TREATMENT OF

PALSY AND APOPLEXY.

And of the Forms, Seats, Complications, and Morbid Relations of Paralytic and Apoplectic Diseases.

BY JAMES COPLAND, M. D., F. R. S., &c.,

In one volume.

THE PATHOLOGICAL ANATOMY OF THE HUMAN BODY.

BY JULIUS VOGEL, M. D., &c.

Translated from the German, with Additions,

BY GEORGE E. DAY, M. D., &c.

ILLUSTRATED BY UPWARDS OF ONE HUNDRED PLAIN AND COLORED ENGRAVINGS.

In one neat octavo volume.

ALISON'S PATHOLOGY.—Outlines of Pathology and Practice of Medicine; containing Preliminary Observations, Inflammatory and Febrile Diseases, and Chronic or non-Febrile Diseases. In one neat 8vo. volume. pp. 420.

ABERCROMBIE ON THE STOMACH.—Pathological and Practical Researches on Diseases of the Stomach. Intestinal Canal, &c. Fourth Edition. One small 8vo. volume, pp. 320.

ABERCROMBIE ON THE BRAIN.—Pathological and Practical Researches on Diseases of the Brain and Spinal Cord. A new edition, in one small 8vo. volume, pp. 324.

BURROWS ON CEREBRAL CIRCULATION.—On Disorders of the Cerebral Circulation, and on the Connection between Affections of the Brain and Diseases of the Heart. In one 8vo. vol., with colored plates, pp 216.

BLAKISTON ON THE CHEST.—Practical Observations on certain Diseases of the Chest, and on the Principles of Auscultation. In one volume, 8vo., pp. 384.

BILLING'S PRINCIPLES.—The First Principles of Medicine. From the Fourth London Edition. In one volume, 8vo., pp. 304.

BIRD ON URINARY DEPOSITS.—Urinary Deposits, their Diagnosis, Pathology, and Therapeutical Indications. In one volume, 8vo., pp 228.

HASSE'S PATHOLOGICAL ANATOMY.—An Anatomical Description of the Diseases of Respiration and Circulation. Translated and Edited by Swaine. In one volume, 8vo., pp. 379.

HUGHES ON THE LUNGS AND HEART.—Clinical Introduction to the Practice of Auscultation, and other modes of Physical Diagnosis. In one 12mo. volume, with a plate, pp. 270.

WALSHE ON THE LUNGS.—Physical Diagnosis of the Diseases of the Lungs. In one 12mo. vol., pp. 310.

CONTENTS OF

GRIFFITH'S UNIVERSAL FORMULARY.

THE FORMULARY PROPER OCCUPIES BETWEEN THREE AND FOUR HUNDRED PAGES, DOUBLE COLUMNS.

From Prof. W. T. Wilson, of Baltimore.

GENTLEMEN.—On carefully looking over the volume, I am satisfied that it will fill up a place occupied by no previous publication. Besides the Formulary proper, it embraces such a variety of other and necessary matter, nowhere else contained within the compass of a single volume—for instance, all the minor details connected with compounding, prescribing and administering medicines, the general management of the sick room, dietetic and officinal preparations: the subject of baths, blood-letting, poisons, &c., together with copious indices, as must make it an indispensable hand-book to the junior practitioner, and a valuable addition to the library, or rather table, (for it is a book not only to be read, but *used*,) of every practising physician.

ELLIS'S MEDICAL FORMULARY.—Improved Edition.

THE MEDICAL FORMULARY:

BEING A COLLECTION OF PRESCRIPTIONS, DERIVED FROM THE WRITINGS AND PRACTICE OF MANY OF THE MOST EMINENT PHYSICIANS OF AMERICA AND EUROPE.

To which is added an Appendix, containing the usual Dietetic Preparations and Antidotes for Poisons.

THE WHOLE ACCOMPANIED WITH A FEW BRIEF PHARMACEUTIC AND MEDICAL OBSERVATIONS.

BY BENJAMIN ELLIS, M. D.

NINTH EDITION, CORRECTED AND EXTENDED, BY SAMUEL GEORGE MORTON, M. D.

In one neat octavo volume of 268 pages.

MOHR, REDWOOD, AND PROCTER'S PHARMACY.—Just Issued.

PRACTICAL PHARMACY.

COMPRISING THE ARRANGEMENTS, APPARATUS, AND MANIPULATIONS OF THE PHARMACEUTICAL SHOP AND LABORATORY.

BY FRANCIS MOHR, Ph. D.,
Assessor Pharmaciæ of the Royal Prussian College of Medicine, Coblentz;
AND THEOPHILUS REDWOOD,
Professor of Pharmacy in the Pharmaceutical Society of Great Britain.
EDITED, WITH EXTENSIVE ADDITIONS, BY PROFESSOR WILLIAM PROCTER,
Of the Philadelphia College of Pharmacy.

In one handsomely printed octavo volume, of 570 pages, with over 500 engravings on wood.

In presenting the work of Mohr and Redwood to the American Pharmaceutical public, it is under the impression that the want of a treatise on the apparatus and manipulations of Practical Pharmacy has long been felt. The Practice of Pharmacy, as conducted in England and in the United States, is sufficiently alike to render this work appropriate as a handbook for the American Apothecary; and the eminence of the authors in their respective countries, is a guarantee of the value of the information it contains. In passing through the hands of the Editor, the book has been increased more than one-fourth in size, about one hundred wood-cuts have been added, the arrangement of the subjects materially changed, and the work divided into chapters, each of which includes either one distinct subject, or several that have a certain generic relation to each other. One object sought by the change of arrangement has been to fit the work as a text-book for the Editor's class in the Philadelphia College of Pharmacy, as far as its nature will admit, and some of the additions have been made with a view to the same object.—EDITOR'S PREFACE.

From Prof. Lewis C. Beck, of the Albany Medical College.

It is a *capital book*, and ought to be in the hands of every apothecary in the country. I shall strongly recommend it to my class in the Albany Medical College.

From Professor C. G. Page, of Washington.

Truly a valuable work, and one which I have long desired to see. The authors have been so full and careful in the detail of their illustrations and descriptions, that a careful study of the work would be almost equivalent to an apprenticeship in the laboratory. It will give me great pleasure to commend it to the profession.

After a pretty thorough examination, we can recommend it as a highly useful book, which should be in the hands of every apothecary. Although no instruction of this kind will enable the beginner to acquire that practical skill and readiness which experience only can confer, we believe that this work will much facilitate their acquisition, by indicating means for the removal of difficulties as they occur, and suggesting methods of operation in conducting pharmaceutic processes which the experimenter would only hit upon after many unsuccessful trials; while there are few pharmaceutists, of however extensive experience, who will not find in it valuable hints that they can turn to use in conducting the affairs of the shop and laboratory.

The mechanical execution of the work is in a style of unusual excellence. It contains about five hundred and seventy large octavo pages, handsomely printed on good paper, and illustrated by over five hundred remarkably well executed wood-cuts of chemical and pharmaceutical apparatus. It comprises the whole of Mohr and Redwood's book, as published in London, rearranged and classified by the American editor, who has added much valuable new matter, which has increased the size of the book more than one-fourth, including about one hundred additional wood-cuts.—*The American Journal of Pharmacy.*

It is difficult to convey a satisfactory idea of a work of this kind, treating as it does, of many various subjects, in the limited space at our disposal, and we are conscious that in this hasty notice we have given a very inadequate impression of its merits. It is a book, however, which will be in the hands of almost every one who is much interested in pharmaceutical operations, as we know of no other publication so well calculated to fill a void long felt in the absence of a practical work of this character.—*The Medical Examiner.*

NEW AND COMPLETE MEDICAL BOTANY. Lately Published.

MEDICAL BOTANY;

OR, A DESCRIPTION OF ALL THE MORE IMPORTANT PLANTS USED IN MEDICINE, AND OF THEIR PROPERTIES, USES, AND MODES OF ADMINISTRATION.

BY R. EGLESFELD GRIFFITH, M. D., &c. &c.

In one large 8vo. vol. of 704 pages, handsomely printed, with nearly 350 illustrations on wood.

One of the greatest acquisitions to American medical literature. It should by all means be introduced at the very earliest period, into our medical schools, and occupy a place in the library of every physician in the land.—*Southwestern Medical Advocate.*

Admirably calculated for the physician and student—we have seen no work which promises greater advantages to the profession.—*N. O. Medical and Surgical Journal.*

One of the few books which supply a positive deficiency in our medical literature.—*Western Lancet.*

We hope the day is not distant when this work will not only be a text-book in every medical school and college in the Union, but find a place in the library of every private practitioner.—*N. Y. Jour. of Medicine.*

CARPENTER ON ALCOHOLIC LIQUORS. Just Ready.

A PRIZE ESSAY

ON THE USE OF ALCOHOLIC LIQUORS IN HEALTH AND DISEASE.

BY WILLIAM B. CARPENTER, M. D.,
Author of "Principles of Human Physiology," &c.
In one 12mo. volume.

A prize of one hundred guineas having been offered for the best Essay on the above subject, that sum was awarded to Dr. Carpenter for this volume, by the adjudicators, Dr. John Forbes, Dr. G. L. Roupell, and Dr. W. A. Guy. Emanating from so distinguished a physiologist, and giving a clear and connected view of a subject of such universal interest, it cannot fail in attracting general attention.

ROYLE'S MATERIA MEDICA.

MATERIA MEDICA AND THERAPEUTICS;

INCLUDING THE

Preparations of the Pharmacopœias of London, Edinburgh, Dublin, and of the United States,

WITH MANY NEW MEDICINES.

BY J. FORBES ROYLE, M. D., F. R. S.,

Professor of Materia Medica and Therapeutics, King's College, London, &c. &c.

EDITED BY JOSEPH CARSON, M. D.,

Professor of Materia Medica in the Philadelphia College of Pharmacy, &c. &c.

WITH NINETY-EIGHT ILLUSTRATIONS.

In one large octavo volume, of about seven hundred pages.

Being one of the most beautiful Medical works published in this country.

This work is, indeed, a most valuable one, and will fill up an important vacancy that existed between Dr. Pereira's most learned and complete system of Materia Medica, and the class of productions on the other extreme, which are necessarily imperfect from their small extent.—*British and Foreign Medical Review.*

Of the various works on the plan of the one before us, there is none more deserving of commendation. Every one who can afford it, should possess this excellent work.—*Medical Examiner.*

We cannot too highly recommend this valuable work, both to the student and practitioner.—*Southern Journal of Medicine and Pharmacy.*

This work is ably done—the botanical part with great skill; and the chemical, natural history, and therapeutic department most perfect and complete.—*Edinburgh Medical Journal.*

The subject is well treated, the matter practical and well arranged, and we do not hesitate to recommend it as a most useful volume to the student and practitioner.—*Medical Gazette.*

The wood engravings by which the crystals, the vegetable products, and the medicinal animals are illustrated, are better than anything hitherto attempted in Materia Medica, and must prove a great assistance to the student, appealing as they do more powerfully to the mind than the most careful verbal descriptions taken alone could do.—*Lancet.*

ILLUSTRATED ENCYCLOPÆDIA OF MATERIA MEDICA.

THE ELEMENTS

OF MATERIA MEDICA AND THERAPEUTICS.

COMPREHENDING THE NATURAL HISTORY, PREPARATION, PROPERTIES, COMPOSITION, EFFECTS, AND USES OF MEDICINES.

BY JONATHAN PEREIRA, M. D., F. R. S. AND L. S.,

Member of the Society of Pharmacy at Paris; Examiner in Materia Medica and Pharmacy in the University of London; Lecturer on Materia Medica at the London Hospital, &c. &c.

Second American Edition, Enlarged and Improved.

WITH NOTES AND ADDITIONS, BY JOSEPH CARSON, M. D.

In two volumes octavo, containing Fifteen Hundred very large pages, illustrated by 275 Wood-cuts.

Notwithstanding the large size of this work, and the immense quantity of matter contained in its closely printed pages, it is offered at a price so low as to place it within the reach of all.

An Encyclopædia of knowledge in that department of medical science—by the common consent of the profession the most elaborate and scientific Treatise on Materia Medica in our language.—*Western Journal of Medicine and Surgery.*

This Encyclopædia of Materia Medica, for such it may justly be entitled, gives the fullest and most ample exposition of Materia Medica and its associate branches of any work heretofore published in the English language.—*N. Y. Journal of Medicine.*

The work will be found an invaluable storehouse of information for the physician and medical teacher, and we congratulate the profession of this country that it is now placed within their reach.—*Amer. Med. Journal.*

An authoritative and unerring pharmacological guide.—*Medical Examiner.*

DISPENSATORY AND FORMULARY.

A DISPENSATORY AND THERAPEUTICAL REMEMBRANCER. Comprising the entire lists of Materia Medica, with every Practical Formula contained in the three British Pharmacopœias. With relative Tables subjoined, illustrating by upwards of six hundred and sixty examples, the Extemporaneous Forms and Combinations suitable for the different Medicines.

BY JOHN MAYNE, M. D., L. R. C. S., EDIN., &c. &c.

EDITED, WITH THE ADDITION OF THE FORMULÆ OF THE UNITED STATES PHARMACOPŒIA,

BY R. EGLESFELD GRIFFITH, M. D.

In one 12mo. volume, of over three hundred large pages.

The neat typography, convenient size, and low price of this volume, recommend it especially to physicians, apothecaries, and students in want of a pocket manual.

THE THREE KINDS OF COD-LIVER OIL,

Comparatively considered, with their Chemical and Therapeutic Properties,

BY L. J. DE JONGH, M. D.

TRANSLATED, WITH AN APPENDIX AND CASES, BY EDWARD CAREY, M. D.

To which is added an article on the subject from "Dunglison on New Remedies."

In one small 12mo. volume, extra cloth.

WATSON'S PRACTICE OF MEDICINE—New Edition.

LECTURES ON THE

PRINCIPLES AND PRACTICE OF PHYSIC.

DELIVERED AT KING'S COLLEGE, LONDON,

BY THOMAS WATSON, M. D., &c. &c.

Third American, from the last London Edition.

REVISED, WITH ADDITIONS, BY D. FRANCIS CONDIE, M. D.
Author of "A Treatise on the Diseases of Children," &c.

IN ONE OCTAVO VOLUME,

Of nearly ELEVEN HUNDRED LARGE PAGES, strongly bound with raised bands.

To say that it is the very best work on the subject now extant, is but to echo the sentiment of the medical press throughout the country.—*N. O. Medical Journal.*

Of the text-books recently republished Watson is very justly the principal favorite.—*Holmes' Report to Nat. Med. Assoc.*

By universal consent the work ranks among the very best text-books in our language.—*Ill. and Ind. Med. Journal.*

Regarded on all hands as one of the very best, if not the very best, systematic treatise on practical medicine extant —*St. Louis Med. Journal.*

Confessedly one of the very best works on the principles and practice of physic in the English or any other language.—*Med. Examiner.*

As a text-book it has no equal; as a compendium of pathology and practice no superior —*N. Y. Annalist.*

We know of no work better calculated for being placed in the hands of the student, and for a text-book. On every important point the author seems to have posted up his knowledge to the day.—*Amer. Med. Journal.*

One of the most practically useful books that ever was presented to the student—indeed, a more admirable summary of general and special pathology, and of the application of therapeutics to diseases, we are free to say, has not appeared for very many years The lecturer proceeds through the whole classification of human ills, *a capite ad calcem*, showing at every step an extensive knowledge of his subject, with the ability of communicating his precise ideas in a style remarkable for its clearness and simplicity.—*N. Y. Journal of Medicine and Surgery.*

A careful examination of this volume has satisfied us that it merits all the commendation bestowed on it in this country and at home. It is a work adapted to the wants of young practitioners. combining, as it does, sound principles and substantial practice It is not too much to say that it is a representative of the actual state of medicine as taught and practised by the most eminent physicians of the present day, and as such we would advise every one about embarking in the practice of physic to provide himself with a copy of it.—*Western Journal of Medicine and Surgery.*

We have for several years considered this one of the best works extant on the Principles and Practice of Medicine. Its style is adapted to all classes of readers, and the views of the author are sound and practical. —*Mo. Med. and Surg. Journal.*

THE GREAT MEDICAL LIBRARY.

THE CYCLOPEDIA OF PRACTICAL MEDICINE;

COMPRISING

Treatises on the Nature and Treatment of Diseases, Materia Medica, and Therapeutics, Diseases of Women and Children, Medical Jurisprudence, &c. &c.

EDITED BY

JOHN FORBES, M. D., F. R. S., ALEXANDER TWEEDIE, M. D., F. R. S. AND JOHN CONNOLLY, M. D.

Revised, with Additions,

BY ROBLEY DUNGLISON, M. D.

THIS WORK IS NOW COMPLETE, AND FORMS FOUR LARGE SUPER-ROYAL OCTAVO VOLUMES,

Containing Thirty-two Hundred and Fifty-four unusually large Pages in Double Columns, Printed on Good Paper, with a new and clear type.

THE WHOLE WELL AND STRONGLY BOUND WITH RAISED BANDS AND DOUBLE TITLES.

Or, to be had in Twenty-four Parts.

This work contains no less than FOUR HUNDRED AND EIGHTEEN DISTINCT TREATISES,

By Sixty-eight distinguished Physicians.

The most complete work on Practical Medicine extant; or, at least, in our language.—*Buffalo Medical and Surgical Journal.*

For reference. it is above all price to every practitioner.—*Western Lancet.*

One of the most valuable medical publications of the day—as a work of reference it is invaluable.—*Western Journal of Medicine and Surgery.*

It has been to us, both as learner and teacher. a work for ready and frequent reference, one in which modern English medicine is exhibited in the most advantageous light.—*Medical Examiner.*

We rejoice that this work is to be placed within the reach of the profession in this country, it being unquestionably one of very great value to the practitioner. This estimate of it has not been formed from a hasty examination, but after an intimate acquaintance derived from frequent consultation of it during the past nine or ten years. The editors are practitioners of established reputation, and the list of contributors embraces many of the most eminent professors and teachers of London, Edinburgh, Dublin, and Glasgow. It is, indeed, the great merit of this work that the principal articles have been furnished by practitioners who have not only devoted especial attention to the diseases about which they have written, but have also enjoyed opportunities for an extensive practical acquaintance with them.—and whose reputation carries the assurance of their competency justly to appreciate the opinions of others, while it stamps their own doctrines with high and just authority.—*American Medical Journal.*

NEW WORK BY DR. CHURCHILL.

ON THE DISEASES OF INFANTS AND CHILDREN.

BY FLEETWOOD CHURCHILL, M. D., M. R. I. A.,
Author of "Theory and Practice of Midwifery," "Diseases of Females," &c.

In one large and handsome octavo volume of over 600 pages.

It is with much gratification that I acknowledge this volume to owe its existence to the solicitations of my excellent American publishers. After making a considerable collection of works on Diseases of Children, I had laid them aside, hopeless of accomplishing the task of writing the work I had contemplated; but it was impossible to decline an invitation so flattering, from a country which had shown so much indulgence to my former works.

I have, therefore, in such leisure as I have been able to command during the last three years, written this volume, not as the exponent of my own experience alone, but as embracing the information recorded by all the authors within my reach, of which I have freely availed myself; and, if it prove useful and acceptable to my American brethren, I shall be richly repaid.—AUTHOR'S PREFACE.

The circumstances under which this work has been prepared are fully set forth in the Author's Preface. The American Publishers, therefore, have only to remark, that its progress through the press has been supervised by a competent member of the profession, who has added a complete and accurate Index of Diseases, as also a copious Bibliographical List of Authors and Works referred to.

From Dr. Churchill's known ability and industry, we were led to form high expectations of this work; nor were we deceived. Its learned author seems to have set no bounds to his researches in collecting information which. with his usual systematic address, he has disposed of in the most clear and concise manner, so as to lay before the reader every opinion of importance bearing upon the subject under consideration.

We regard this volume as possessing more claims to completeness than any other of the kind with which we are acquainted. Most cordially and earnestly, therefore, do we commend it to our professional brethren, and we feel assured that the stamp of their approbation will in due time be impressed upon it.

After an attentive perusal of its contents, we hesitate not to say, that it is one of the most comprehensive ever written upon the diseases of children, and that, for copiousness of reference, extent of research, and perspicuity of detail, it is scarcely to be equalled, and not to be excelled in any language.—*Dublin Quarterly Journal.*

The present volume will sustain the reputation acquired by the author from his previous works. The reader will find in it full and judicious directions for the management of infants at birth, and a compendious, but clear, account of the diseases to which children are liable, and the most successful mode of treating them. We must not close this notice without calling attention to the author's style, which is perspicuous and polished to a degree, we regret to say, not generally characteristic of medical works. We recommend the work of Dr. Churchill most cordially, both to students and practitioners, as a valuable and reliable guide in the treatment of the diseases of children.—*Am. Journ. of the Med. Sciences.*

After this meagre, and we know, very imperfect notice, of Dr. Churchill's work, we shall conclude by saying, that it is one that cannot fail from its copiousness, extensive research, and general accuracy, to exalt still higher the reputation of the author in this country. The American reader will be particularly pleased to find that Dr. Churchill has done full justice throughout his work, to the various American authors on this subject. The names of Dewees, Eberle, Condie, and Stewart, occur on nearly every page, and these authors are constantly referred to by the author in terms of the highest praise, and with the most liberal courtesy.—*The Medical Examiner.*

We know of no work on this department of Practical Medicine which presents so candid and unprejudiced a statement or posting up of our actual knowledge as this.—*N. Y. Journal of Medicine.*

Its claims to merit, both as a scientific and practical work, are of the highest order. Whilst we would not elevate it above every other treatise on the same subject, we certainly believe that very few are equal to it, and none superior.—*Southern Med. and Surg. Journal.*

MUCH ENLARGED AND IMPROVED EDITION—Now Ready.

A PRACTICAL TREATISE ON

INFLAMMATION OF THE UTERUS AND ITS APPENDAGES,

And on Ulceration and Induration of the Neck of the Uterus.

BY HENRY BENNETT, M. D.,
Obstetric Physician to the Western Dispensatory.

Second Edition, much enlarged.

In one neat octavo volume of 350 pages, with wood-cuts.

This edition is so enlarged as to constitute a new work. It embraces the study of inflammation in all the uterine organs, and its influence in the production of displacements and of the reputed functional diseases of the uterus.

Few works issue from the medical press which are at once original and sound in doctrine: but such, we feel assured, is the admirable treatise now before us. The important practical precepts which the author inculcates are all rigidly deduced from facts. . . . Every page of the book is good, and eminently practical. So far as we know and believe, it is the best work on the subject on which it treats.—*Monthly Journal of Medical Science.*

A TREATISE ON THE DISEASES OF FEMALES.

BY W. P. DEWEES, M. D.

NINTH EDITION.

In one volume, octavo. 532 pages, with plates.

MEIGS ON FEMALES.

FEMALES AND THEIR DISEASES;

A SERIES OF LETTERS TO HIS CLASS.

BY C. D. MEIGS, M. D.,

Professor of Midwifery and the Diseases of Women and Children in the Jefferson Medical College of Philadelphia, &c. &c.

In one large and beautifully printed octavo volume of 670 pages.

He has evidently seen almost every form and variety of female disease, and not only seen, but observed and reflected, and if we may judge by the innate evidence afforded by the volume itself, practised successfully. His volume contains many practical hints and suggestions which will repay perusal.—*The Charleston Medical Journal and Review.*

The work is written in a free, animated conversational style, and is replete with sound practical instruction.—*The Western Lancet.*

We warmly commend the work of Professor Meigs as a highly interesting and instructive volume.—*N. Y. Journal of Medicine.*

The remaining affections of the womb, included in the volume before us, are treated of very learnedly, and much valuable instruction is communicated concerning them. Dr. Meigs' views as to the nature and causes of these affections are generally correct, while his long and extensive experience gives to his practical directions no trifling weight. The work contains a very large fund of valuable matter, and will, in all probability, become a very popular one.—*American Medical Journal.*

They are full of instruction. It would be difficult to point to a volume containing more valuable information relative to females and their diseases.—*The Western Journal of Medicine and Surgery.*

We feel that in this hasty sketch we have given the reader scarcely an idea of the vast amount of useful information which the book contains, and of the pleasing style in which, generally, it is conveyed, and most conscientiously advise him to purchase and read it for himself.—*The Annalist.*

Every chapter is replete with practical instruction, and bears the impress of being the composition of an acute and experienced mind. There is a terseness, and at the same time an accuracy, in his description of symptoms, and in the rules for diagnosis, which cannot fail to recommend the volume to the attention of the reader.—*Ranking's Abstract.*

MEIGS AND COLOMBAT ON FEMALES.

NEW AND IMPROVED EDITION, JUST ISSUED.

A TREATISE ON THE DISEASES OF FEMALES,

AND ON

THE SPECIAL HYGIENE OF THEIR SEX.

WITH NUMEROUS WOOD-CUTS.

BY COLOMBAT DE L'ISÈRE, M. D.,

Chevalier of the Legion of Honor; late Surgeon to the Hospital of the Rue de Valois, devoted to the Diseases of Females, &c. &c.

TRANSLATED, WITH MANY NOTES AND ADDITIONS,

BY C. D. MEIGS, M. D.,

Professor of Obstetrics and Diseases of Women and Children in the Jefferson Medical College, &c. &c.

SECOND EDITION, REVISED AND IMPROVED.

In one large volume, octavo, of seven hundred and twenty pages.

We are satisfied it is destined to take the front rank in this department of medical science; it is beyond all comparison, the most learned Treatise on the Diseases of Females that has ever been written, there being more than one thousand distinct authorities quoted and collected by the indefatigable author. It is in fact a complete exposition of the opinions and practical methods of all the celebrated practitioners of ancient and modern times. The Editor and Translator has performed his part in a manner hardly to be surpassed. The translation is faithful to the original, and yet elegant. More than one hundred pages of original matter have been incorporated in the text, constituting a seventh part of the whole volume.—*New York Jour. of Medicine.*

ASHWELL ON THE DISEASES OF FEMALES.

A PRACTICAL TREATISE ON THE

DISEASES PECULIAR TO WOMEN.

ILLUSTRATED BY CASES DERIVED FROM HOSPITAL AND PRIVATE PRACTICE.

BY SAMUEL ASHWELL, M. D.

WITH ADDITIONS, BY PAUL BECK GODDARD, M. D.

SECOND AMERICAN EDITION.

In one octavo volume, of five hundred and twenty pages.

One of the very best works ever issued from the press on the Diseases of Females.—*Western Lancet.*

This invaluable work.—*Missouri Medical and Surgical Journal.*

We strongly recommend Dr. Ashwell's Treatise to our readers as a valuable book of reference, on an extensive, complicated, and highly important class of diseases.—*Edinburgh Monthly Journal of Med. Sciences.*

NEW AND IMPROVED EDITION.—Now Ready. (1850.)

CHURCHILL ON FEMALES.

THE DISEASES OF FEMALES,

INCLUDING THOSE OF PREGNANCY AND CHILDBED.

BY FLEETWOOD CHURCHILL, M. D., M. R. I. A.,

Author of "Theory and Practice of Midwifery," "Diseases of Females," &c.

A New American Edition (The Fifth), Revised by the Author.

WITH THE NOTES OF ROBERT M. HUSTON, M. D.

In one large and handsome octavo volume of 632 pages, with wood-cuts.

PREFACE TO THE FIFTH EDITION.

The object of the following work was to combine the valuable information scattered through the various periodicals, or published as monographs, with that contained in the larger volumes, and to present the whole in a form equally suitable for the student and practitioner. With this view, as I mentioned in the preface to the first edition, I had arranged "that the text should contain an ample outline of the history, pathology, symptoms, and treatment of the diseases, without any detail of controversies or conflicting opinions, which are given in full in the notes appended to each page; so that the student, by confining his attention to the text, may acquire elementary information, which may be subsequently extended by consulting the notes and references. In the notes, likewise, will be found extracts from various authors, wherein the support of their opinions seemed desirable. I have preferred giving their views in their own words, as being less liable to be mistaken. Where extracts were not deemed advisable, references are given, and considerable care has been taken to have them correct."

That others felt the want of such a work as I had myself, and that, to a certain extent, my object was attained, I think I may assume from the number of editions which have been called for.

For reasons which are now unimportant, the second part, on the Diseases of Pregnancy and Childbed, was published separately in England; but the two have been very properly combined in one volume by my American publishers, as they are both constructed on the same plan, and, together, complete the subject of the Diseases of Women.

In the present edition, the valuable notes of my friend, Dr. Huston, have been carefully retained, and I have added considerably both to the text and notes, so that I trust it will be found an improvement upon its predecessors.

Let me, in conclusion, express the gratitude I must ever feel to my American brethren for the kindness with which they have received this, and my other works, and my thankfulness that I have been spared to contribute something, however little, to the cultivation of our noble profession.—*Dublin, December*, 1849.

By reference to the Author's Preface, it will be seen, that his thorough revision of the present edition has rendered unnecessary any material additions by the editor. The notes contained in former editions are retained in this, at the request of Dr. Churchill; and these, rather than anything omitted in the text, have suggested occasional, but brief remarks.

Churchill's Monographs on Females.—Just Ready.

ESSAYS ON THE PUERPERAL FEVER, AND OTHER DISEASES PECULIAR TO WOMEN.

SELECTED FROM THE WRITINGS OF BRITISH AUTHORS PREVIOUS TO THE CLOSE OF THE EIGHTEENTH CENTURY.

Edited by FLEETWOOD CHURCHILL, M. D., M. R. I. A.,

Author of "Treatise on the Diseases of Females," &c.

In one neat octavo volume, of about four hundred and fifty pages.

I have thought it might be useful to prefix to these tracts a short historical sketch of the principal epidemics. I have collected, with some labor, all the information within my reach, and I trust that the summary will be found tolerably complete. I should feel some apology necessary for my own share in this volume, which has been prepared under the pressure of many engagements, were it not for the great intrinsic value that such a collection of original writings, by men of great experience, must possess.—EDITOR'S PREFACE.

A TREATISE

ON THE PHYSICAL AND MEDICAL TREATMENT OF CHILDREN.

BY W. P. DEWEES, M. D.

NINTH EDITION.

In one volume, octavo. 548 pages.

MEIGS ON CERTAIN DISEASES OF INFANTS.

In one octavo volume. Nearly ready.

THE NEW WORK—MEIGS' OBSTETRICS.—Lately Issued.

OBSTETRICS:

THE SCIENCE AND THE ART.

BY CHARLES D. MEIGS, M. D.,

Professor of Midwifery and the Diseases of Women and Children in the Jefferson Medical College, Philadelphia, &c. &c.

With One Hundred and Twenty Illustrations.

In one beautifully printed octavo volume, of six hundred and eighty large pages.

As an elementary treatise—concise, but, withal, clear and comprehensive—we know of no one better adapted for the use of the student; while the young practitioner will find in it a body of sound doctrine, and a series of excellent practical directions, adapted to all the conditions of the various forms of labor and their results, which he will be induced, we are persuaded, again and again to consult, and always with profit.

It has seldom been our lot to peruse a work upon the subject, from which we have received greater satisfaction, and which we believe to be better calculated to communicate to the student correct and definite views upon the several topics embraced within the scope of its teachings.—*American Journal of the Medical Sciences.*

We are acquainted with no work on midwifery of greater practical value.—*Boston Medical and Surgical Journal.*

Worthy the reputation of its distinguished author.—*Medical Examiner.*

We most sincerely recommend it, both to the student and practitioner, as a more complete and valuable work on the Science and Art of Midwifery, than any of the numerous reprints and American Editions of European works on the same subject.—*N. Y. Annalist.*

We have, therefore, great satisfaction in bringing under our reader's notice the matured views of the highest American authority in the department to which he has devoted his life and talents.—*London Medical Gazette.*

An author of established merit, a professor of Midwifery, and a practitioner of high reputation and immense experience—we may assuredly regard his work now before us as representing the most advanced state of obstetric science in America up to the time at which he writes. We consider Dr. Meigs' book as a valuable acquisition to obstetric literature, and one that will very much assist the practitioner under many circumstances of doubt and perplexity.—*The Dublin Quarterly Journal.*

These various heads are subdivided so well, so lucidly explained, that a good memory is all that is necessary in order to put the reader in possession of a thorough knowledge of this important subject. Dr. Meigs has conferred a great benefit on the profession in publishing this excellent work.—*St. Louis Medical and Surgical Journal.*

No reader will lay the volume down without admiration for the learning and talents of the author. An abler volume, on the whole, we do not hope soon to see.—*Western Journal of Medicine and Surgery.*

A safe and efficient guide to the delicate and oftimes difficult duties which devolve upon the obstetrician.—*Ohio Medical and Surgical Journal.*

One of the very best treatises on this subject, and worthy of being placed in the library of every American physician.—*Northwestern Medical and Surgical Journal.*

He has an earnest way with him when speaking of the most elementary subjects which fixes the attention and adds much value to the work as a text-book for students.—*British and Foreign Medico-Chirurgical Review.*

NEW EDITION, REVISED FOR THIS COUNTRY.

THEORY AND PRACTICE OF MIDWIFERY.

BY FLEETWOOD CHURCHILL, M. D.,

Hon. Fellow of the Royal College of Physicians of Ireland, &c. &c.

WITH NOTES AND ADDITIONS

BY ROBERT M. HUSTON, M. D., &c.

THIRD AMERICAN EDITION, REVISED AND IMPROVED BY THE AUTHOR.

With One Hundred and Twenty-eight Illustrations.

In one very handsome octavo volume, of five hundred and twenty-six pages.

This is certainly the most perfect system extant. It is the best adapted for the purposes of a text-book, and that which he whose necessities confine him to one book, should select in preference to all others.—*Southern Medical and Surgical Journal.*

The most popular work on Midwifery ever issued from the American press.—*Charleston Medical Journal.*

Certainly, in our opinion, the very best work on the subject which exists.—*N. Y. Annalist.*

Were we reduced to the necessity of having but *one* work on Midwifery, and *permitted to choose*, we would unhesitatingly take Churchill.—*Western Medical and Surgical Journal.*

It is impossible to conceive a more useful and elegant Manual than Dr. Churchill's Practice of Midwifery.—*Provincial Medical Journal.*

No work holds a higher position, or is more deserving of being placed in the hands of the tyro, the advanced student, or the practitioner.—*Medical Examiner.*

CONTENTS OF THE

AMERICAN JOURNAL OF THE MEDICAL SCIENCES. April, 1850.

ORIGINAL COMMUNICATIONS.

MEMOIRS AND CASES. pp. 291–402.

Art. I. Warren on the Prevention of Constipation. II. Kirkbride on Heating and Ventilating Hospitals and other Buildings, by Steam and Hot Water. (With three wood cuts) III. Atlee on Large Peritoneal Section. IV. Dalton's Case of Malformation of the Cranium, Encephalon, and Spinal Cord. (With eight wood-cuts.) V. Buckingham's Cases of Labor. (With five wood-cuts.) VI. Morland's Extracts from the Records of the Boston Society for Medical Improvement. VII. Bemis' Case of Hydrophobia. VIII Bennett on the Identity of Erysipelas and a certain form of Puerperal Fever. and its Contagiousness. IX. Peaslee's Case of Rupture of the Bladder, together with Seven Fractures of the Pelvis. X. McSherry's Medical Cases. XI. Griffin's Case of Ascites. in which the patient was tapped, in ten years, one hundred and eighty-six times, and had seven hundred and fifty-one and three-fourths gallons of water drawn off.

REVIEWS. pp. 402–434.

XII. 1. Traité Théorique et Pratique des Luxations Congénitales du Fémur. Par le Doct. Ch. G. Pravaz. 4to. pp 288, with ten plates. 2. A Treatise on the Etiology, Pathology, and Treatment of Congenital Dislocations of the Head of the Femur. With plates. By M. Carnochan, M. D. 8vo. XIII. The Transactions of the American Medical Association. Vol. II.

BIBLIOGRAPHICAL NOTICES. pp. 435–474.

XIV. A Universal Formulary: containing the Methods of Preparing and Administering Officinal and other Medicines. By R. E. Griffith, M. D 8vo. XV. An Introductory Lecture. By J. Knight, M. D. 8vo. XVI. Lectures on Electricity and Galvanism. By G. Bird, M. D. 12mo. Notes on the Medical Application of Electricity. By W. F. Channing. 12mo. XVII. Curabilité de la Phthisie et des Scrofules. Par A. M. Riofrey. 8vo. XVIII Report of the Committee of the Legislature of Massachusetts on a Sanitary Survey of the State. 8vo. XIX. An Essay on Intestinal Auscultation. By C. Hooker, M. D. 8vo. XX. Observations on Asiatic Cholera. By J. Evans. 8vo XXI. The History of the Cholera in Exeter in 1832. By T. Shapter, M. D. 8vo. XXII. Remarks on Obstetrical Forceps. By J. P. White, M. D. 8vo. XXIII. A Practical Treatise on Inflammation of the Uterus and its Appendages. By J. H. Bennet, M. D. 8vo. XXIV. A Treatise on Midwifery. By P. Cazeaux. Translated by R. P. Thomas, M. D 8vo. XXV. Medico-Chirurgicale Clinique et Iconographie. Par M. Anvert. XXVI. An Introductory Lecture. By P. F. Eve, M. D. 8vo.

QUARTERLY SUMMARY.

FOREIGN INTELLIGENCE.

ANATOMY AND PHYSIOLOGY. pp. 475–478.

1. *Blanchet* on Hearing independent of the Auditory Nerve. 2. *Brown Séquard* on Regeneration of the Sciatic Nerve. 3. *Brown Séquard* on the Pathological Changes that follow Section of the Sciatic Nerve. 4. *De Froberville* on the Ostro-Negroes of Eastern Africa. 5. *Frerichs* on the Uses of the Pancreas.

ORGANIC CHEMISTRY. pp. 478–481.

6. *Plouviez* on Experiments on the Use of Salt. 7. *Jones*' Contributions to the Chemistry of the Urine.

MATERIA MEDICA AND PHARMACY. pp. 481–483.

8. *Rivallier* on Monohydrated Nitric Acid as a Caustic. 9. *Hannon* on Pharmaceutical Preparations of Manganese.

MEDICAL PATHOLOGY AND THERAPEUTICS AND PRACTICAL MEDICINE. pp. 483–503.

10. *Jenner* on the Identity or Non-identity of Typhoid Fever, Typhus Fever, and Relapsing Fever. 11. *Benson* on the Use of Cod-Liver Oil—its Effect in producing Congestion of the Lung. 12. *Bennett* on Tubercular Exudation into the Lungs—Diseased Aortic Valves—Musical Heart-Sounds—Ulceration in the Lungs checked by Cod-Liver Oil. 13. *Walton* on Conversion of Tubercle into Earthy Matter. 14. *Mauthner* on Bloodletting in the Pneumonia of Children. 15. *Sibson* on Falling in of the Chest during Inspiration, in some Diseases of the Chest. 16. *Fliess* on Paralysis which attends Dentition. 17. *Schneider* on Sulphuric Acid in Singultus. 18. *Brown* on the Diagnosis of Ovarian Dropsy. 19. *Popham* on Obstructions of the Rectum from the Use of Diseased Potatoes. 20. *Griffith* on the so called Cholera Bodies. 21. *Robertson* on Cholera (?) Corpuscles. 22. *Benson* on the Gutta Percha Stethoscope.

SURGICAL PATHOLOGY AND THERAPEUTICS AND OPERATIVE SURGERY. pp. 503–521.

23. *Banon* on Aneurism of the Popliteal Space treated successfully by Compression. 24. *Madden* on Popliteal Aneurism treated by Compression. 25. *Taylor* on Chronic Hydrocephalus—Tapping—Death. 26. *Nevins* on Tapping in Spina Bifida. 27. A Case of Dislocation of the Neck successfully treated by Mechanical Means. 28. *Sedillot* on Gastrotomy for Impassable Stricture of the Œsophagus—Death in twenty-four hours. 29. *Field* and *Clarkson's* two Cases of Complete Intestinal Obstruction arising from Disease of the Sigmoid Flexure of the Colon and the Rectum, in which the Descending Colon was successfully opened in the Loin. 30 *Robert* on Annular Stricture of the Rectum. 31. *Fritze* on the Statistics of the Mortality from Fractures of the Head. 32 *Blick* on Large Punctured Wound of the Rectum and Dislocation of the Coccyx. 33. *Canton* on Ununited Comminuted Fracture of the Surgical Neck of the Humerus; also, Unreduced Dislocation of the Radius forwards at the Elbow, with Partial Luxation of the Ulna inwards. 34. *Simpson* on the Use of the Exploring Needle in Pelvic and other Tumors. 35. *Raciborski's* Method of Preventing the Ingress of Air in evacuating large Collections of Fluid. 36. *Tufnell* on Gutta Percha Bougies.

OPHTHALMOLOGY. pp. 521–525.

37. *Jacob* on Tumors of the Eye and Orbit. 38. *Canton* on Hysterical Ptosis.

MIDWIFERY. pp. 525–532.

39. *Diday* on a New Method of Plugging the Vagina, &c. 40. *Lever* on the Use and Advantages of Opium in the Practice of Obstetricy. 41. *Webster* on Insanity from the Use of Chloroform during Parturition. 42. *Cormack* on Puerperal Convulsions—their dependence on Toxæmia. 43 *Kesteven's* Examination into the Grounds of the Ovular Theory of Menstruation. 44. *Gillette* on Pregnancy in a Female who had never Menstruated. 45. *Rogers* on Vicarious Menstruation. 46. *Tyler Smith* on the Length of the Umbilical Cord.

MEDICAL JURISPRUDENCE AND TOXICOLOGY. pp. 532–537.

47. *Miller* on Infanticide—Retention of Life after Long Exposure. 48. *Brachet* on the Cessation of the Heart's Sounds as a Sign of Death. 49. *Bernard* on the Action of Amygdaline and Emulsine. 50. *Landsberg*. Vagitus Uterinus. 51. *Simpson* on Fatal Venous Hemorrhage from the Pudendu. 52. *Christison* on Poisoning with Hydrocyanic Acid. 53. *Mitscherlich* on the Poisonous Effects of Oil of Cinnamon.

MISCELLANEOUS. pp. 537–541.

54. *Davy* on Action of Lime on Animal and Vegetable Substances.

(CONTINUED ON PAGE 32.)

CONTENTS OF JOURNAL. (Continued from page 31.)

AMERICAN INTELLIGENCE.